Glaciological investigations in Norway in 2002

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Glaciological investigations in Norway in 2002

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Frontpage photo:	Lower part of Rembesdalskåka, a south-western outlet glacier of Hardangerjøkulen. Mass balance studies have been performed since 1963, and front position measurements were started in 1995 at this glacier. The photo is taken on 14th October 2003 by Hallgeir Elvehøy.
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Abstract:	Results of glaciological investigations performed at Norwegian glaciers in 2002 are presented in this report. The main part concerns mass balance investigations. Results from investigations of glacier monitoring are discussed in a separate chapter.
Subjects:	Glaciology, Mass balance, Front position, Ice movement

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Preface

This report is a new volume in the series "Glaciological investigations in Norway" which has been published since 1963.

The report is based on a number of reports on different investigations of Norwegian glaciers. Measurements of mass balance, front position change, glacier velocity, and other glaciological investigations are presented. Most of the investigations are ordered by external companies and have been published earlier as reports to the respective companies.

The report is published in English with a summary in Norwegian. The purpose of this report is to provide a joint presentation of the investigations and calculations made mainly by NVEs Section for Glaciers and Environmental Hydrology during 2002. Even though the chapters are written by different authors with different objectives, a uniform pattern is the aim. The authors had the professional responsibility for the content of each chapter. The fieldwork and the calculations are mainly a result of co-operative work amongst the employees at the Section for Glaciers and Environmental Hydrology.

Bjarne Kjøllmoen was editor and Miriam Jackson made many corrections and improvements.

Oslo, 12 December 2003

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Summary

Mass balance investigations were performed on twelve glaciers in Norway in the year 2002. Eight of these glaciers are in southern Norway and four in northern Norway.

The winter balance was approximately average for the measured glaciers in the northern part of western Norway and higher than average in the southern part. In Jotunheimen the results were 15-25 % lower than average. In northern Norway the winter balance was approximately average. Notice that melting *after* the final measurements in the autumn 2001 occurred at some of the glaciers. This melting is included as a *negative* contribution to the 2002 winter *balance* which is somewhat lower than the 2002 winter *accumulation*.

The warm summer resulted in extreme values of summer balance at several glaciers. In northern Norway, Langfjordjøkelen had the largest summer balance since measurements began in 1989. In southern Norway the results were between 148 and 198 % of average. Ålfotbreen, Hansebreen, Nigardsbreen, Austdalsbreen and Storbreen had the highest summer balances ever recorded.

Due to the warm summer with great ablation the net balance was negative at all twelve of the measured glaciers. The greatest deficit was measured at Austdalsbreen (-2.0 m w.eqv.), Hansebreen (-1.9 m w.eqv.) and Storbreen (-1.8 m w.eqv.). For six of the glaciers the equilibrium line altitude was *above* the glacier summit.

Front position measurements were performed for 24 Norwegian glaciers in 2002. Nineteen of the glaciers are in southern Norway and five in northern Norway. The results show a retreat in front position for most of the measured glaciers from autumn 2001 to autumn 2002. At Jostedalsbreen the front position of the outlets Fåbergstølsbreen and Store Supphellebre retreated most with nearly 30 metres. Nigardsbreen was approximately steady state, while Austerdalsbreen had a measurable advance of 5 metres. All measured outlets from Hardangerjøkulen and Folgefonna had retreated during the last one-year period. Measurements from Jotunheimen show recessions for all glaciers except Storgjuvbreen which had a small advance of 4 metres. In northern Norway Engabreen (Svartisen) had a moderate retreat (6 m) while Langfjordjøkelen (in western Finnmark) had a marked frontal retreat of 62 metres.

Sammendrag

I 2002 ble det utført massebalansemålinger på 12 breer i Norge – åtte i Sør-Norge og fire i Nord-Norge.

For de målte breene på Vestlandet ble vinterbalansen omtrent som gjennomsnittet nord for Sognefjorden og litt over gjennomsnittet lenger sør. I Jotunheimen ble resultatene 15-25 % mindre enn gjennomsnittet. I Nord-Norge ble vinterbalansen omtrent som normalt. På flere av breene forekom det noe smelting *etter* de avsluttende målingene høsten 2001. Den reelle *snøakkumulasjonen* på disse breene er dermed litt større enn den presenterte *vinterbalansen*.

Den varme sommeren førte til at det ble rekordstor sommerbalanse på flere breer. I Nord-Norge fikk Langfjordjøkelen den største sommerbalansen siden målingene startet i 1989. I Sør-Norge ble resultatene mellom 148 og 198 % av gjennomsnittet. Det ble notert rekordhøy sommerbalanse på Ålfotbreen, Hansebreen, Nigardsbreen, Austdalsbreen og Storbreen.

På grunn av den varme sommeren med stor avsmelting ble det negativ nettobalanse på samtlige av de 12 målte breene. Størst underskudd ble det på Austdalsbreen (-2,0 m), Hansebreen (-1,9 m) og Storbreen (-1,8 m). På seks av breene lå likevektslinjen *over* breens høyeste punkt.

Frontmålinger ble utført på 24 norske breer i 2002, 19 i Sør-Norge og 5 i Nord-Norge. Resultatene viser tilbakegang på de fleste breutløperne i hele landet fra høsten 2001 til høsten 2002. På Jostedalsbreen hadde utløperne Fåbergstølsbreen og Store Supphellebre størst tilbakegang med nærmere 30 meter. Frontposisjonen på Nigardsbreen var omtrent uforandret, mens Austerdalsbreen hadde en liten framgang på 5 meter. Alle de målte utløperne fra Hardangerjøkulen og Folgefonna hadde tilbakegang. Målinger fra Jotunheimen viser tilbakegang for alle breutløperne unntatt Storgjuvbreen som hadde en liten framgang på 4 meter. I Nord-Norge hadde fronten på Engabreen en liten tilbakegang på 6 meter, mens Langfjordjøkelen hadde en markert tilbakegang med 62 meter.

1. Glacier investigations in Norway in 2002

1.1 Mass balance

Studies of mass balance include measurements of accumulated snow (winter balance) during the winter season, and measurements of snow and ice removed by melting (summer balance) during the summer season. The difference between these two parameters gives the net balance. If the winter balance is greater than the summer balance, the net balance is positive and the glacier increases in volume. Alternatively, if the melting of snow and ice during the summer is larger than the winter balance, the net balance is negative and the ice volume decreases.

Method

The method used to measure mass balance is the same as used in previous years. Using experience gained from many years of measurements, the measurement network was simplified on individual glaciers at the beginning of the 1990s, without affecting the accuracy of the resulting balance calculations or the final results.

The winter balance is normally measured in April or May by probing to the previous year's summer surface along the same profile each year. Stake readings are used to verify the probings where possible. Since the stakes can disappear during particularly snow-rich winters, and since it is often difficult to distinguish the summer surface (S.S.) by probing alone, snow coring is also used to confirm the probing results. Snow density is measured in pits at one or two locations at different elevations on each glacier.

Summer and net balances are obtained from stake measurements, usually carried out in September or October. Below the glacier's equilibrium line the net balance is always negative, meaning that more snow and ice melts during a given summer than accumulates during the winter. Above the equilibrium line, in the accumulation area, the net balance is always positive. Based on past experience snow density of the remaining snow in the accumulation area is typically assumed to be 0.60 g/cm^3. After especially cold summers, or if there is more snow than usual remaining at the end of the summer, snow density is measured using snow-cores, or is assumed to be 0.65 g/cm^3. The density of melted older firn is assumed to be between 0.65 and 0.75 g/cm^3. The density of melted ice is set to 0.90 g/cm^3.

The mass balance is usually calculated using the so-called traditional stratigraphic method (Østrem and Brugman 1991), which means the balance between two successive "summer surfaces" (i.e. surface minima). Consequently the measurements describe the state of the glacier *after* end of melting and *before* fresh snow has fallen. In some occasions ablation *after* the final measurements in September/October can occur. Strictly speaking, this ablation should be included in this year's summer balance. However, measuring and calculating this additional ablation cannot be done until the following winter or spring. Thus, it is counted as a negative contribution to the next year's winter balance.

The accuracy of the mass balance measurements depends on several factors. The accuracy of the winter balance is influenced mainly by the accuracy of the point measurements (soundings, core drillings, stakes, towers and density pit) and how representative they are. The evenness of the snow layer is also of importance. The accuracy of soundings and core drillings is dependent on the number of point measurements, the certainty of identifying the summer surface and the implementation of the measurements (e.g. if the probe penetrates vertically through the snow pack). Overall, the accuracy of winter balance increases with increasing snow depth.

The accuracy of summer balance is primarily dependent on the number of stakes at which melting is measured. Further, it depends on how representative are the stakes and on the state of the stakes. Common sources of error are stakes sinking or tilting to one side.

The accuracy of the net balance is dependent on all the factors mentioned above.

As the mass balance is measured and calculated it is very difficult to estimate the accuracy mathematically because it is difficult to quantify the accuracy of the individual factors. The determined values of accuracy are therefore based on a subjective estimate.

Mass balance program

In 2002 mass balance measurements were performed on 12 glaciers in Norway - 8 in southern Norway and 4 in northern Norway. In southern Norway, 6 of the glaciers have been measured for 40 consecutive years or more. They constitute a west-east profile extending from the very maritime Ålfotbreen glacier with an average winter balance of 3.7 m water equivalent, to the very continental Gråsubreen with an average winter balance of 0.8 m w.eqv. Storbreen in Jotunheimen has the longest series of all glaciers in Norway with 54 years of measurements, while Engabreen has the longest series (33 years) in northern Norway. In 2002 mass balance measurements began on Rundvassbreen, a northwest-oriented outlet from Blåmannsisen in Nordland county. The location of the glaciers investigated is shown in Figure 1-1.

In the following chapters mass balance studies performed on Norwegian glaciers in 2002 are reported. The numbers from the Norwegian Hydrological Unit System (REGINE) and from the World Glacier Monitoring Service (WGMS) are given for each glacier in Table 1-1.

The mass balance (winter, summer and net balance) is given both in volume (m^3 water) and specific water equivalents for each 50 or 100 m height interval. The results are given in both tables and diagrams. All diagrams have the same ratio between units on the x- and y-axes in order to make comparison straightforward.

Finally, histograms showing the complete mass balance results for each glacier are presented.

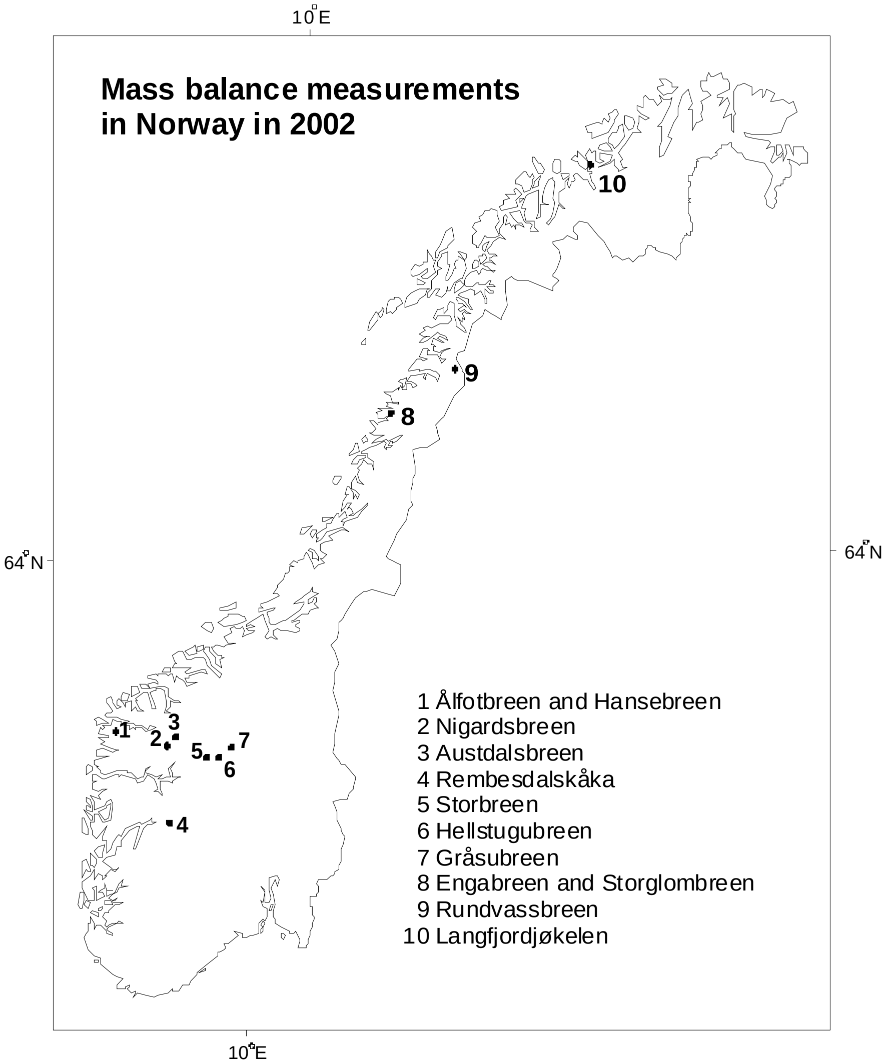


Figure 1-1
Location of the glaciers at which mass balance studies were performed in 2002.

Weather conditions and mass balance results

In northern Norway the winter months October-December 2001 had approximately normal meteorological conditions (baseline period is 1961-1990) in West-Finnmark and Nordland. However, the precipitation was a little below normal in the border areas in Salten (Blåmannsisen). November had most precipitation with 100-150 % of normal for the province. In Nordland, December was dry with about 50 % of normal. In western Norway there was more precipitation than usual north of Sognefjorden and less than normal south of Sognefjorden during the last three months of 2001. In Jotunheimen the winter months October-December were approximately average. The winter season January-April was warmer and had more precipitation than normal over the whole country. In West-Finnmark January and March had the most precipitation comparatively (150 %), while April was correspondingly dry (50 %). Nordland had more precipitation than normal during the period January-April, but somewhat less than normal in April in the Salten area. In western Norway and Jotunheimen the precipitation was approximately 25 % more than normal during the winter months January-April. February and March had most precipitation with up to 200 % in some areas, while April was the driest comparatively with 25-75 % of normal.

The winter balance was about average for the measured glaciers in the northern part of western Norway (except Austdalsbreen) and somewhat higher than average in the southern part. In Jotunheimen the results were 15-25 % lower than average. In northern Norway the winter balance was approximately average. Notice that melting *after* the final measurements in autumn 2001 occurred at some the glaciers. This will influence primarily the results for Austdalsbreen, Storbreen, Hellstugubreen, Storglombreen abd Engabreen. This melting is included as a *negative* contribution to the 2002 winter *balance*. Thus, the real snow *accumulation* is somewhat greater than the presented winter *balance* at these glaciers.

The mean temperature for the whole country during the summer season May-September 2002 was 2.1 ºC above normal, which is the highest mean summer temperature ever measured since measurements started in 1866. August was particularly warm with 4-5 ºC higher temperature than normal in southern Norway and 3-4 ºC higher in Nordland.

The warm summer resulted in an extreme summer balance at several glaciers. In northern Norway Langfjordjøkelen had the largest summer balance since measurements began in 1989. In southern Norway the results were between 148 and 198 % of average. Ålfotbreen, Hansebreen, Nigardsbreen, Austdalsbreen and Storbreen had the highest summer balances ever recorded. The greatest relative summer balance was measured at the glaciers in Jotunheimen.

Due to the warm summer with great ablation the net balance was negative at all twelve measured glaciers. The greatest deficit was measured at Austdalsbreen (-2.0 m w.eqv.), Hansebreen (-1.9 m w.eqv.) and Storbreen (-1.8 m w.eqv.). For six of the glaciers the equilibrium line altitude was *above* the glacier summit.

The results from the mass balance measurements in Norway in 2002 are shown in Table 1-1. Winter ($\mathbf{b_{w,}}$), summer ($\mathbf{b_s}$) and net balance ($\mathbf{b_n}$) are given in metres water equivalent (m w.eqv.) smoothly distributed over the entire glacier surface. The figures in the **% of average** column show the current results in percent of the average for the previous years (minimum eight years of measurements). The net balance results are compared with the mean net balance in the same way. **ELA** is the equilibrium line altitude.

Figure 1-2 gives a graphical presentation of the mass balance results in southern Norway for 2002. The west-east gradient is evident for both winter and summer balances.

Glacier	Number code WGMS	REGINE	Period	Area (km^2)	b_w (m)	% of average	b_s (m)	% of average	b_n (m)	b_n middle	ELA
Ålfotbreen	*BL004*	*086.6C1B*	1963-02	4.5	3.78	101	-5.31	156	-1.53	0.33	>1382
Hansebreen	*BO002*	*086.6E*	1986-02	3.1	3.51	100	-5.44	148	-1.93	-0.15	>1327
Nigardsbreen	*A4014*	*076.EZ*	1962-02	47.8	2.41	100	-3.30	172	-0.89	0.48	1715
Austdalsbreen	*A4023*	*076.H*	1988-02	11.8	1.91	83	-3.92[1]	177	-2.01	0.10	>1757
Rembesdalskåka	*AO001*	*050.4C1Z*	1963-02	17.1	2.39	113	-3.10	160	-0.71	0.19	1750
Storbreen	*AD041*	*002.DHBBZ*	1949-02	5.4	1.09	75	-2.87	173	-1.78	-0.20	>2100
Hellstugubreen	*AD011*	*002.DHBAZ*	1962-02	3.0	0.96	85	-2.37	175	-1.41	-0.26	2080
Gråsubreen	*AB047*	*002.DGDC*	1962-02	2.3	0.63	80	-2.05	198	-1.42	-0.25	>2290
Storglombreen	*C7013/ C7014*	*160.C*	1985-88 2000-02	59.0 62.4	2.33	116[2]	-3.58	137[2]	-1.23	-0.61[2]	>1580
Engabreen	*C4011*	*159.81*	1970-02	38.0	2.89	98	-3.48	145	-0.59	0.71	1200
Rundvassbreen	[3]	*166.D1*	2002-	11.6	2.14	-	-3.19	-	-1.05	-	1320
Langfjordjøkelen	*ET008*	*211.33A*	1989-02	3.7	2.19	98[4]	-3.73	130[4]	-1.54	-0.64[4]	>1050

[1]Contribution from calving amounts to 0.35 m for b_s
[2]Calculated for the measured periods 1985-88 and 2000-2001
[3]WGMS number D1021 and D1022
[4]Calculated for the measured periods 1989-93 and 1996-2001

Table 1-1
Review of the results from mass balance measurements performed in Norway in 2002. The glaciers in southern Norway are listed from west to east. Each glacier is reported in two different number systems. The first column denotes the numbers used in the reports to the World Glacier Monitoring Service (WGMS). All ID's begin with N4A000, so only the last five characters are shown here. The second column gives numbers from the Norwegian Hydrological Unit System (REGINE).

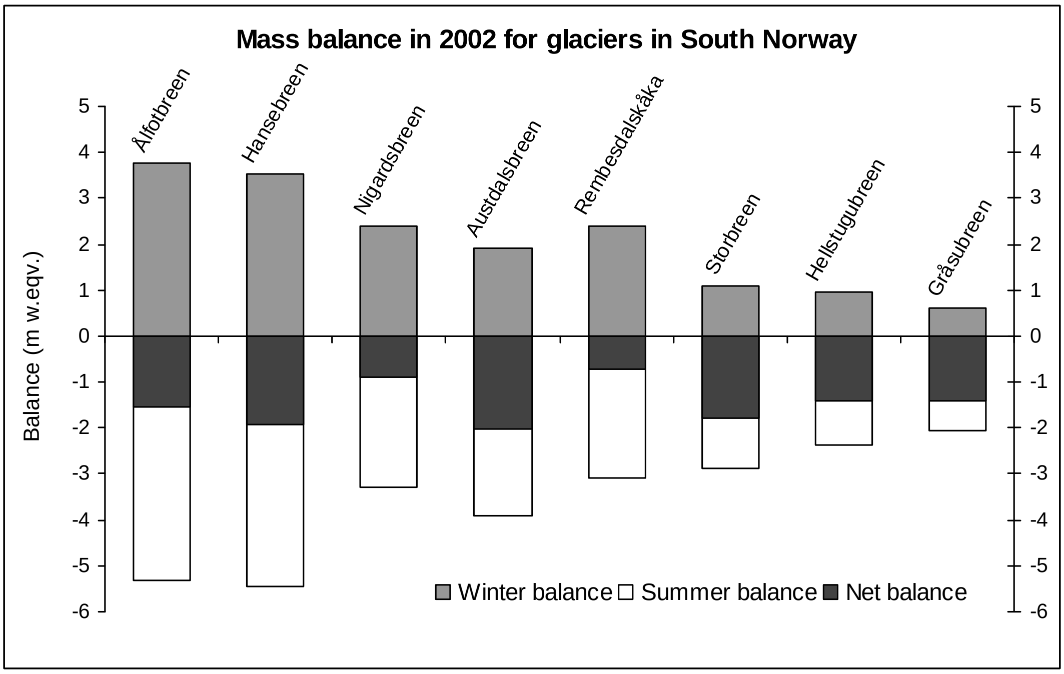


Figure 1-2
Mass balance 2002 in southern Norway. The glaciers are listed from west to east.

The cumulative net balance for some of the glaciers in southern Norway during the period 1963-2002 is shown in Figure 1-3. The maritime glaciers – Ålfotbreen, Nigardsbreen and Hardangerjøkulen – have increased in volume, while Storbreen and Gråsubreen in Jotunheimen show a distinct decrease in net balance. The considerable surplus for the maritime glaciers is mainly a result of some winters with high snowfall between 1989 and 1995.

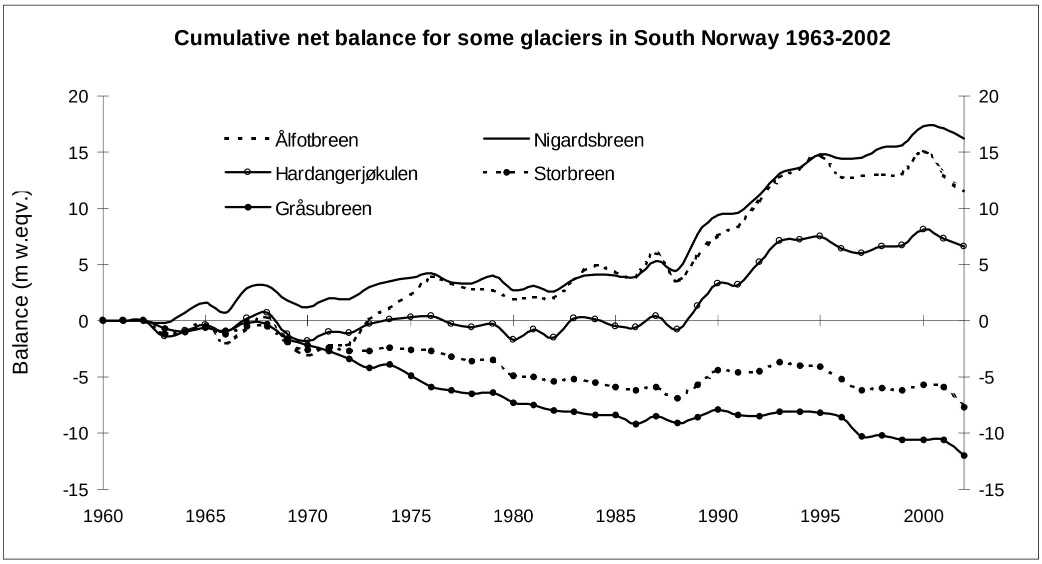


Figure 1-3
Cumulative net balance for Ålfotbreen, Nigardsbreen, Hardangerjøkulen, Storbreen and Gråsubreen during the period 1963-2002. Ålfotbreen and Nigardsbreen have a considerable surplus, most of this was acquired between 1989 and 1995.

1.2 Other investigations

Front position measurements were performed at 24 glaciers in Norway in 2002. Some of these have measurements going back to ca. 1900. As well as being presented in a separate chapter (chap. 14), the front position changes are described for each glacier in its respective chapter.

A number of measurements were performed at Svartisheibreen during the period 1988-94 (Kjøllmoen & Kennett 1995). Mass balance, ice movement, front position change, surface elevation and water level in a small lake in front of the glacier terminus (Heiavatnet) were measured. Annual observations of water level in Heiavatnet, equilibrium line altitude and changes in ice thickness on the snout have been performed since 1995 and were continued in 2002 (chap. 9).

Svartisen Subglacial Laboratory was initiated in 1992 and has since been used by researchers from several different countries (Jackson 2000). An overview of activities in the laboratory is given in chapter 10.

2. Ålfotbreen (Bjarne Kjøllmoen)

Ålfotbreen ice cap (61°45’N, 5°40’E) is 17 km^2, and is both the westernmost and the most maritime glacier in Norway. Mass balance studies have been carried out on two adjacent north-facing outlet glaciers - Ålfotbreen (4.5 km^2) and Hansebreen (3.1 km^2). The westernmost of these has been the subject of mass balance investigations since 1963, and has always been reported as Ålfotbreen. On Hansebreen the investigations started in 1986. None of the outlet glaciers from the icecap are given names on the official maps. To distinguish the two different glaciers the last one has been given the name Hansebreen. Ålfotbreen, including its component parts and surroundings, is shown in Figure 2-1.

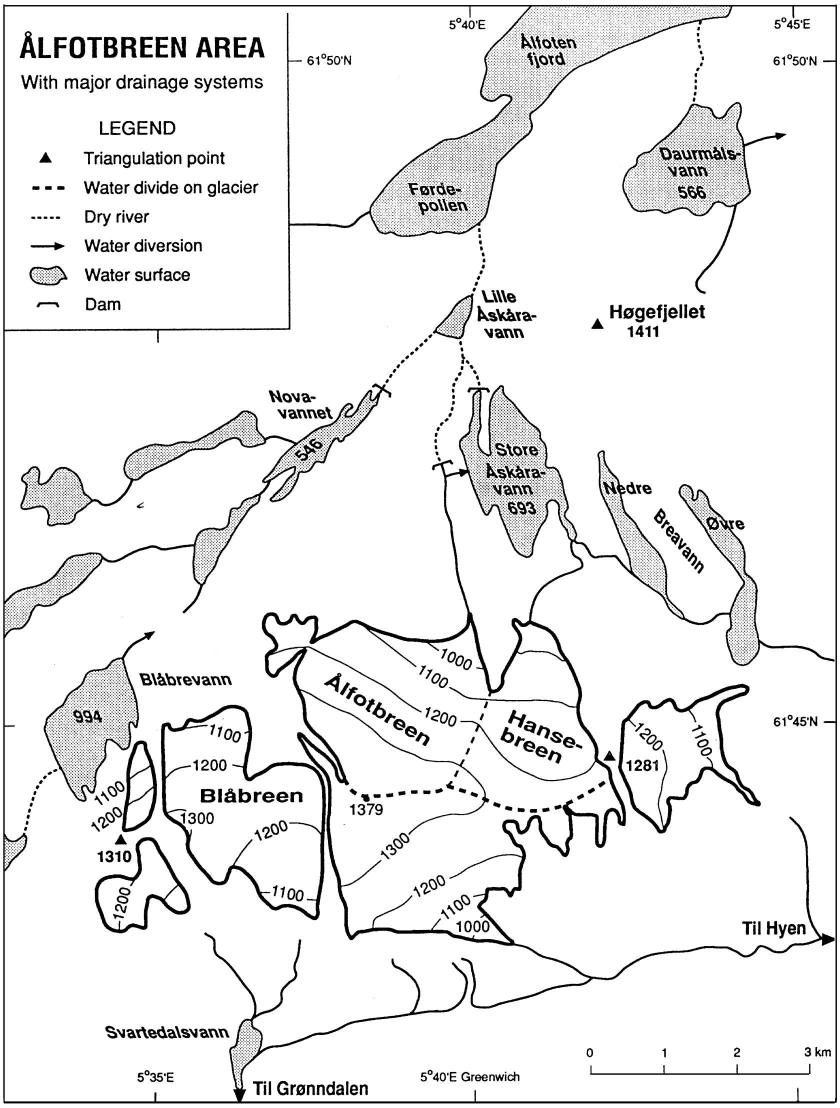


Figure 2-1
Ålfotbreen ice cap and surrounding area, showing the two north-facing glaciers Ålfotbreen and Hansebreen at which mass balance studies are performed.

2.1 Mass balance 2002

Fieldwork

Snow accumulation measurements were performed from 5th to 7th of April. The calculation of winter balance at Ålfotbreen and Hansebreen is based on (Fig. 2-2):

- Measurements of stake replacements and older stakes that appeared during the melt season at positions 26 (1135 m a.s.l.), 45 (1180 m a.s.l.), 37 (1225 m a.s.l.) and 49 (1380 m a.s.l.) at Ålfotbreen, and at positions 50 (1015 m a.s.l.), 60 (1070 m a.s.l.), 80 (1125 m a.s.l.) and 85 (1195 m a.s.l.) at Hansebreen.
- 87 snow depth soundings along a total of about 13 km of profiles at Ålfotbreen, and 59 snow depth soundings along about 9 km of profiles at Hansebreen. The snow depth varied between 6 and 7 m at both glaciers. The summer surface (SS) could easily be identified over the entire glacier.
- Snow density was measured down to the SS (5.5 m) at stake position 37.

The location of stakes, tower, density pit and sounding profiles are shown in Figure 2-2.

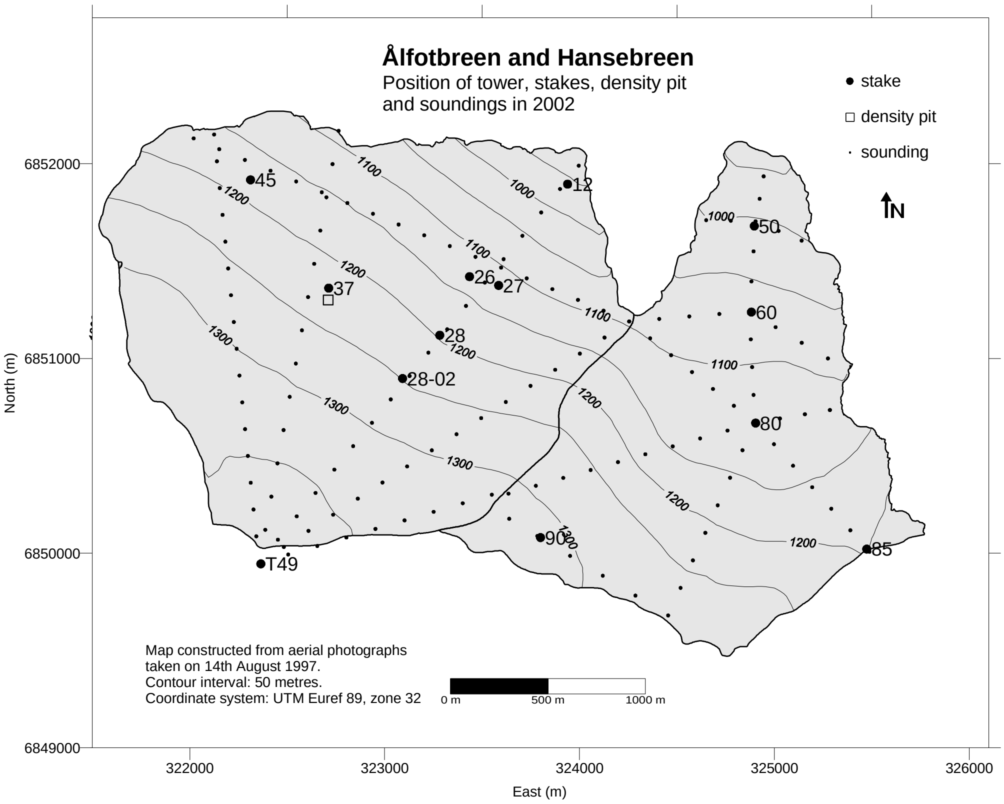


Figure 2-2
Location of stakes, soundings and density pit at Ålfotbreen and Hansebreen in 2002.

Ablation was measured on 5th and 6th of October. The net balance was directly measured on stakes in six different positions between 960 and 1380 m a.s.l. at Ålfotbreen, and at five stake positions between 1025 and 1305 m a.s.l. at Hansebreen.

There was no snow remaining on the glacier surface from the winter 2000/2001, and above 1150 m a.s.l. there was obviously old firn. However, it was rather difficult to determine the boundary between old firn and ice. At the summit of Ålfotbreen there had been net melting of 1.4 m firn since autumn 2001. At the time of the ablation measurements no fresh snow had fallen.

Results

The calculations are based on a glacier map from 1997.

Winter balance

The calculation of winter balance is based on point measurements of snow depth (stakes, tower and probings) and on measurement of snow density in one location. There was no melting after the final measurements in October 2001.

A density profile was modelled from the snow density measured at 1225 m a.s.l. The mean snow density of 5.5 m snow was 0.526 g/cm^3. The density model was assumed to be representative for both Ålfotbreen and Hansebreen, and all snow depths were converted to water equivalents using this model.

The calculation of winter balance was performed by plotting the point measurements (water equivalents) in a diagram. A curve was drawn based on a visual evaluation (Fig. 2-4) and a mean value for each 50 m height interval was estimated (Tab. 2-1).

Winter balance at Ålfotbreen in 2002 was 3.8 ±0.2 m w.eqv., corresponding to a volume of 17 ±1 mill. m^3 of water. The result is 101 % of the mean winter balance for 1963-2001, and 92 % of the mean for 1986-2001 (same period as Hansebreen).

The winter balance at Hansebreen was 3.5 ±0,2 m w.eqv., corresponding to a volume of 11 ±1 mill. m^3 of water. The result is 100 % of the mean value for the period of investigation.

The winter balance was also calculated using a gridding method based on the aerial distribution of the snow depth measurements (Fig. 2-3). Water equivalents for each cell in a 100 x 100 m grid were calculated and summarized. Using this method, which is a control of the traditional method, gave exactly the same results as above.

Summer balance

The density of melted firn was estimated at between 0.65 and 0.75 g/cm^3, while the density of melted ice was estimated as 0.90 g/cm^3.

The summer balance at Ålfotbreen was measured and calculated directly at five stakes. The summer balance increased from nearly -5 m w.eqv. in the uppermost parts of the glacier to about -7 m at the lower parts. Based on estimated density and stake measurements the summer balance for Ålfotbreen was calculated as -5.3 ±0.3 m w.eqv., corresponding to -24 ±1 mill. m^3 of water. The result is 156 % of the average between 1963 and 2001, and 149 % of the average between 1986 and 2001. This is the greatest summer balance ever measured at Ålfotbreen since measurements started in 1963.

The summer balance for Hansebreen was measured and calculated at 5 stakes and increased from -5 m w.eqv. in the upper parts, to approx. -7 m in the lower parts. Based on the 5 stakes and the estimated density the summer balance was calculated to -5.4 ±0.3 m w.eqv. or -17 ±1 mill. m^3 of water. The result is 148 % of the mean value and is the greatest summer balance measured since 1986.

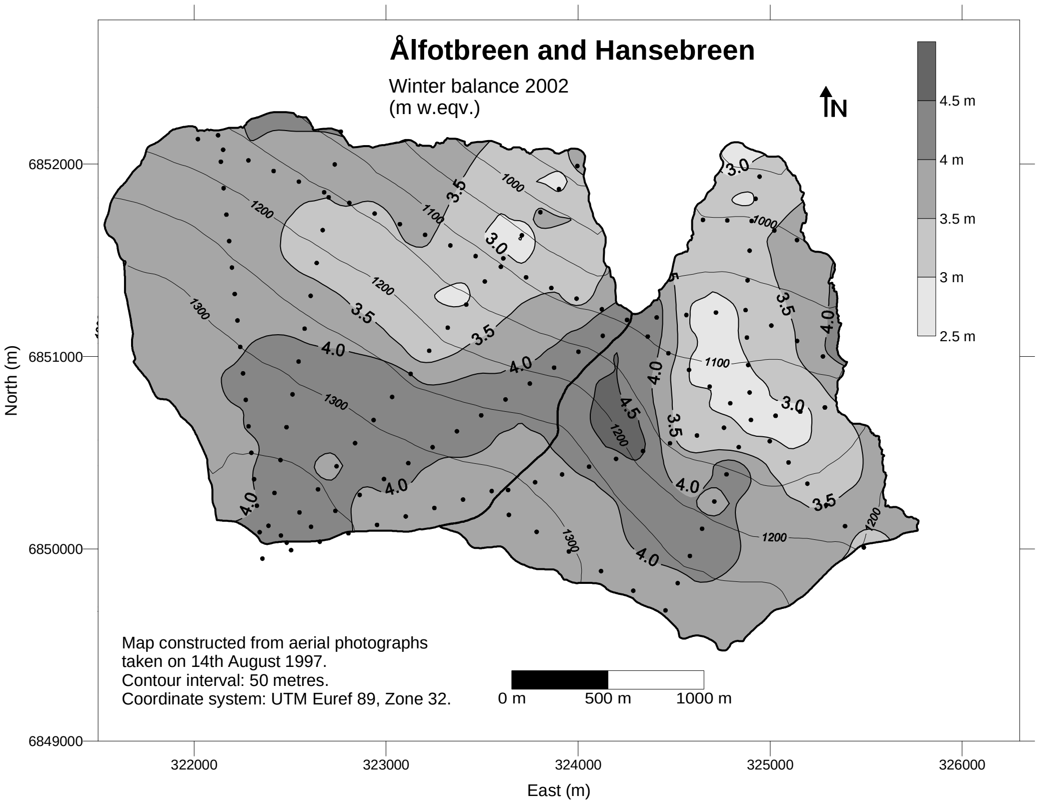


Figure 2-3
Winter balance at Ålfotbreen and Hansebreen in 2002 interpolated from 146 snow depth measurings (•).

Net balance

The net balance at Ålfotbreen for 2002 was calculated as -1.5 ±0.4 m w.eqv., or a volume loss of 7 ±2 mill. m^3 of water. The mean net balance over 1963-2001 is +0.33 m w.eqv., and +0.54 m during 1986-2001 (comparable to Hansebreen).

The net balance at Hansebreen was calculated as -1.9 ±0.4 m w.eqv., or a deficit of 6 ±1 mill. m^3 of water. The mean value for the period 1986-2001 is -0.15 m w.eqv.

With net ablation over the entire glacier surface the equilibrium line altitude lies *above* the highest summit (Fig. 2-4) at both glaciers. Consequently, the AAR is 0 %.

The mass balance results are shown in Table 2-1. The corresponding curves for specific and volume balance are shown in Figure 2-4. The historical mass balance results are presented in Figure 2-5.

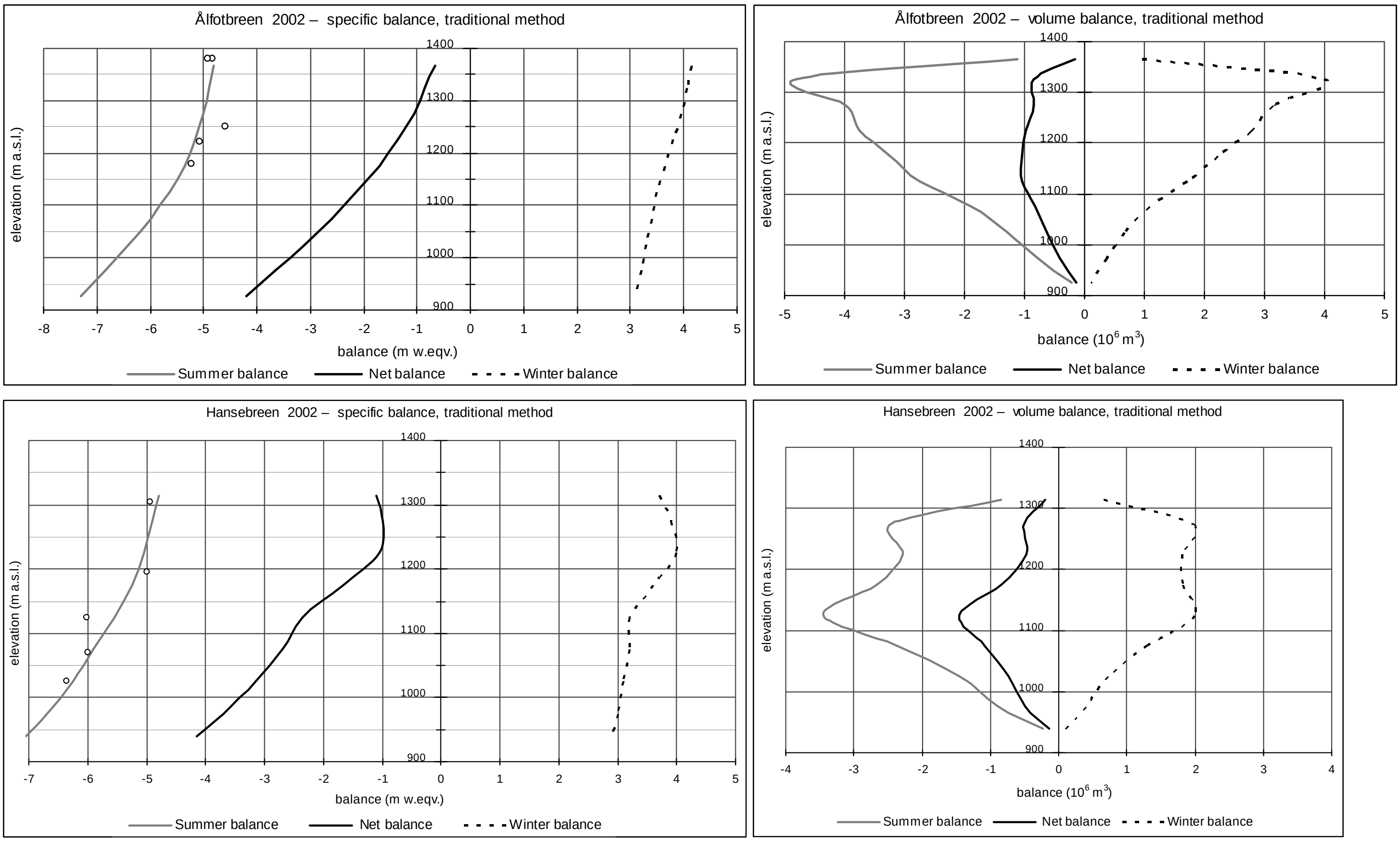


Figure 2-4
Mass balance diagram for Ålfotbreen (upper) and Hansebreen (lower) in 2002 showing altitudinal distribution of specific (left) and volumetric (right) winter, summer and net balance. Specific summer balance at each stake is shown (○).

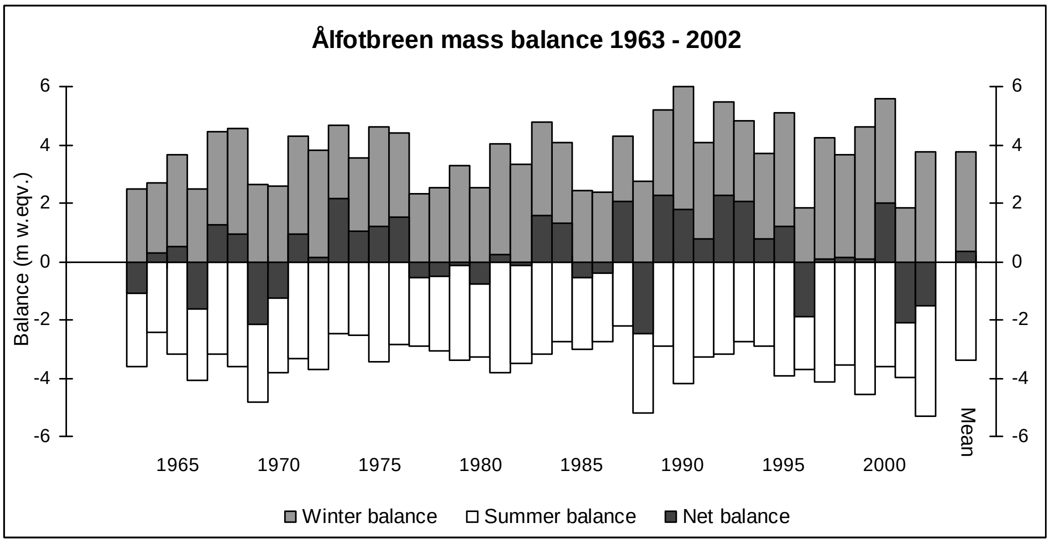
Mass balance Ålfotbreen 2001/02 – traditional method

Altitude (m a.s.l.)	Area (km^2)	Winter balance Measured 5th May 2002		Summer balance Measured 5th Oct 2002		Net balance Summer surfaces 2001 - 2002	
		Specific (m w.eq.)	Volume (10^6 m^3)	Specific (m w.eq.)	Volume (10^6 m^3)	Specific (m w.eq.)	Volume (10^6 m^3)
1350 - 1382	0,23	4,15	1,0	-4,80	-1,1	-0,65	-0,2
1300 - 1350	0,98	4,05	4,0	-4,90	-4,8	-0,85	-0,8
1250 - 1300	0,80	3,95	3,1	-5,00	-4,0	-1,05	-0,8
1200 - 1250	0,73	3,80	2,8	-5,15	-3,8	-1,35	-1,0
1150 - 1200	0,61	3,65	2,2	-5,35	-3,3	-1,70	-1,0
1100 - 1150	0,49	3,50	1,7	-5,65	-2,7	-2,15	-1,0
1050 - 1100	0,32	3,40	1,1	-6,00	-1,9	-2,60	-0,8
1000 - 1050	0,20	3,30	0,7	-6,40	-1,3	-3,10	-0,6
950 - 1000	0,11	3,20	0,4	-6,85	-0,8	-3,65	-0,4
903 - 950	0,03	3,10	0,1	-7,30	-0,2	-4,20	-0,1
903 - 1382	**4,50**	**3,78**	**17,0**	**-5,31**	**-23,9**	**-1,53**	**-6,9**

Mass balance Hansebreen 2001/02 – traditional method

Altitude (m a.s.l.)	Area (km^2)	Winter balance Measured 6th May 2002		Summer balance Measured 5th Oct 2002		Net balance Summer surface 2001 - 2002	
		Specific (m w.eq.)	Volume (10^6 m^3)	Specific (m w.eq.)	Volume (10^6 m^3)	Specific (m w.eq.)	Volume (10^6 m^3)
1300 - 1327	0,18	3,70	0,65	-4,80	-0,85	-1,10	-0,19
1250 - 1300	0,50	3,90	1,95	-4,90	-2,46	-1,00	-0,50
1200 - 1250	0,45	4,00	1,81	-5,05	-2,28	-1,05	-0,47
1150 - 1200	0,51	3,60	1,82	-5,25	-2,66	-1,65	-0,84
1100 - 1150	0,62	3,20	1,99	-5,55	-3,44	-2,35	-1,46
1050 - 1100	0,40	3,20	1,29	-5,90	-2,38	-2,70	-1,09
1000 - 1050	0,23	3,10	0,72	-6,25	-1,46	-3,15	-0,74
950 - 1000	0,13	3,00	0,40	-6,70	-0,89	-3,70	-0,49
930 - 950	0,03	2,90	0,09	-7,05	-0,23	-4,15	-0,13
930 - 1327	**3,06**	**3,51**	**10,7**	**-5,44**	**-16,6**	**-1,93**	**-5,9**

Table 2-1
Winter, summer and net balances for Ålfotbreen (upper) and Hansebreen (lower) in 2002. The mean values for Ålfotbreen during the period 1963-2001 are 3.74 m (b_w), -3.41 m (b_s) and +0.33 m w.eqv. (b_n). The corresponding values for Hansebreen during the period 1986-2001 are 3.52 m, -3.67 m and -0.15 m w.eqv.



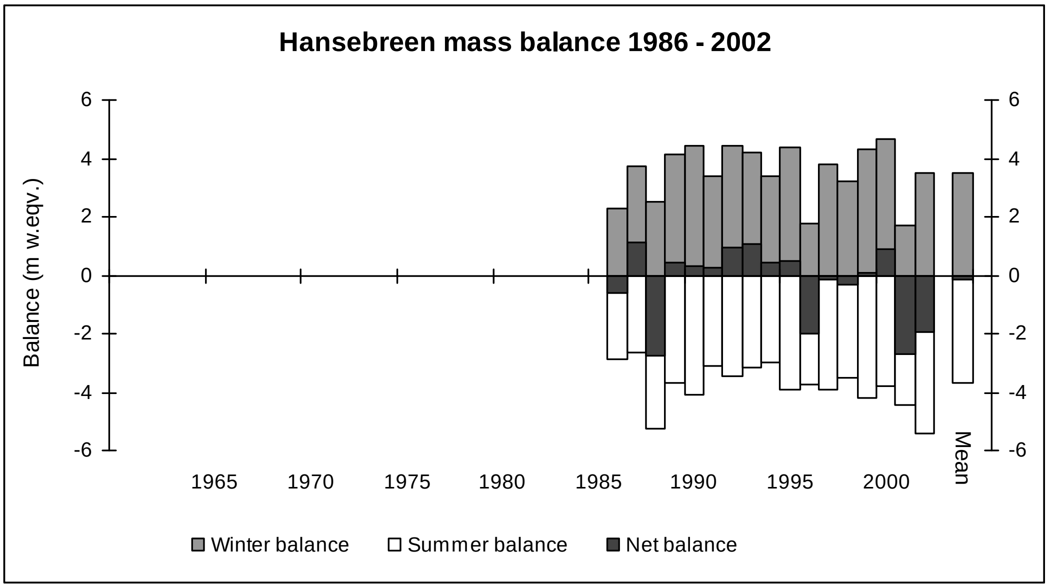


Figure 2-5
Mass balance at Ålfotbreen (upper) during the period 1963-2002 and Hansebreen (lower) during the period 1986-2002.

3. Nigardsbreen (Bjarne Kjøllmoen)

Nigardsbreen (61°42'N, 7°08'E) is one of the largest and most famous outlet glaciers (47.8 km^2, 1984) from Jostedalsbreen, flowing south-east from the centre of the ice cap. Nigardsbreen accounts for approximately 10 % of the total area of Jostedalsbreen, and extends from 1960 m a.s.l. down to approximately 320 m a.s.l.

Glaciological investigations in 2002 include mass balance and front position change. Some observations of the ice-dammed lake Brimkjelen at Tunsbergdalsbreen have also been performed. Nigardsbreen has been the subject of mass balance investigations since 1962.

Figure 3-1
Oblique air photograph of Nigardsbreen taken 31st July 2002. Since 1988 the glacier has advanced about 255 metres. However, over the two last years the front position is nearly unchanged. Photo: Bjarne Kjøllmoen.

3.1 Mass balance 2002

Fieldwork

Snow accumulation measurements were performed 6th and 7th May and the calculation of winter balance is based on (Fig. 3-2):

- Direct measurements of the towers T95 (1685 m a.s.l.) and T56 (1805 m a.s.l.). It was also possible to make use of measurements of substitute stakes drilled in May 2002 and older stakes that appeared during the melt season at positions 54 (1605 m a.s.l.), 57 (1960 m a.s.l.), 94 (1710 m a.s.l.) and 96 (1760 m a.s.l.). Stake readings of 600-98 (615 m a.s.l.) combined with probings indicated 0.9 m ice melting *after* the final measurements in September 2001. The snow depth at 600-98 was 0.7 m.

- Core samples at positions 1000 (1000 m a.s.l.), 53 (1320 m a.s.l.), 54 (1610 m a.s.l.), 94 (1710 m a.s.l.), 96 (1760 m a.s.l.) and 57 (1960 m a.s.l.).
- 162 snow depth soundings along approximately 33 km of profiles between 1320 and 1960 m a.s.l., and some soundings at 615 and 1000 m a.s.l. It was fairly difficult to identify the SS, particularly in areas above 1600 m altitude. Down at the glacier tongue the snow depth was about 0.7 m at 615 m altitude and about 3.0 m at 1000 m altitude. Up on the plateau snow depth varied between 5 and 6 metres.
- Snow density was measured down to 4.4 m depth (SS at 5.0 m) at stake position 53 and down to 5.0 m depth (SS between 5.0 and 5.3 m) at position 57.

Location of stakes, towers, density pit, core samples and sounding profiles are shown in Figure 3-2.

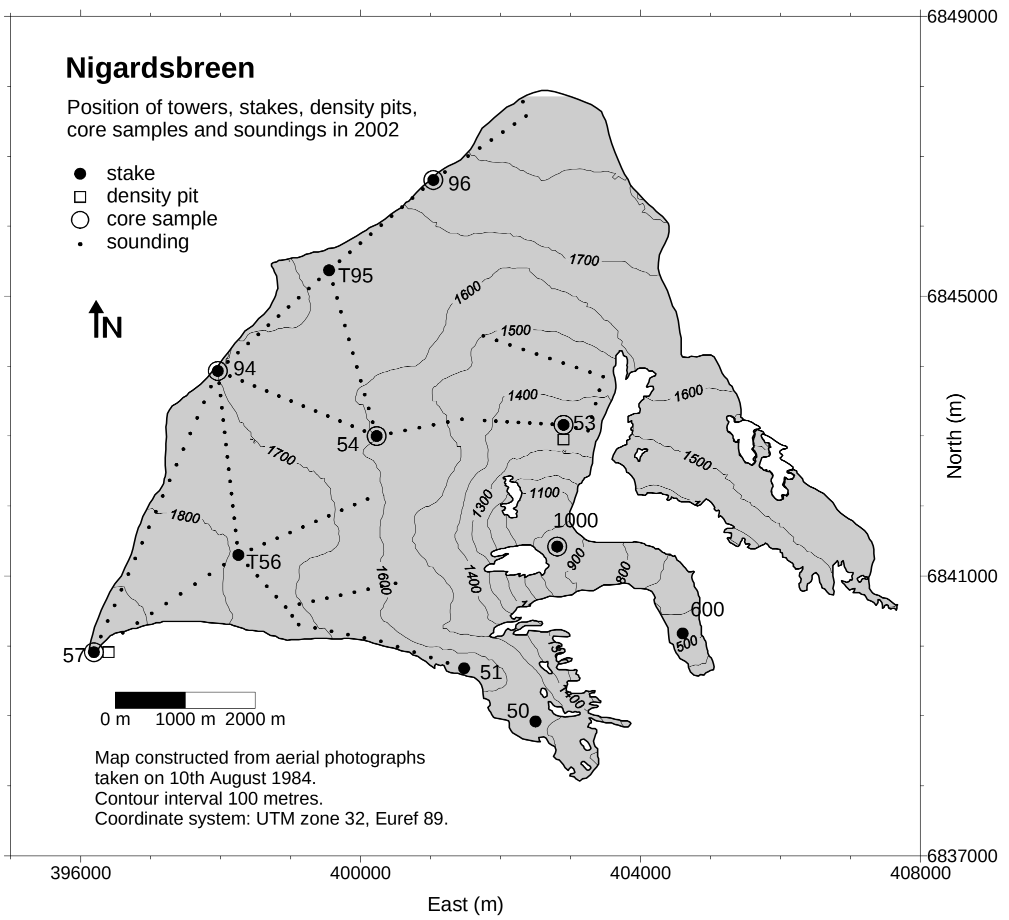


Figure 3-2
Location of towers and stakes, density pits, core samples and sounding profiles at Nigardsbreen in 2002.

Ablation measurements were carried out on 7th October. Measurements were made at 22 stakes/towers in 11 different positions. The net balance was measured directly at stakes in nine different positions between 1320 and 1960 m a.s.l. At 615 and 1000 m altitude, net balance was measured for a limited period of the ablation season. These measurements are supplemented with extrapolated values. There was about 0.5 m of snow remaining at the uppermost areas. Between 25 and 45 cm of fresh snow had fallen in the upper parts of the glacier. On the glacier tongue the net melting between autumn 2001 and autumn 2002 was almost 9 m of ice at 615 m altitude.

Results

The calculations are based on a glacier map from 1984.

Winter balance

The calculation of winter balance is based on point measurements of snow depth (stakes and towers, probings and core drillings) and on measurement of snow density at two locations.

Some ablation occurred *after* the final measurements in September 2001. This ablation is counted as a negative contribution to the winter balance 2001/2002 as described in chapter 1. The negative winter balance contribution was measured and calculated as -0.8 m w.eqv. at 615 m altitude and -0.2 m w.eqv. at 1000 m altitude, in total 0.03 m water equivalent.

Density profiles were modelled from the snow density measured at 1320 m a.s.l. (4.4 m depth) and 1960 m a.s.l. (5.0 m). Using these models gave a snow density of 0.47 g/cm^3 (1320 m a.s.l.) and 0.48 g/cm^3 (1960 m a.s.l.). The model from 1320 m altitude was used for all snow depth measurings carried out *below* 1640 m a.s.l., whereas the model from 1960 m altitude was used for elevations *above* 1640 m a.s.l.

The winter balance calculation was performed by plotting measurements (water equivalents) in a diagram. A curve was drawn based on visual evaluation (Fig. 3-3), and a mean value for each 100 m height interval estimated (Tab. 3-1). The elevations above 1320 m a.s.l. were well represented with point measurements. Below this altitude the curve pattern was based on some probings at 1000 and 615 m altitude.

This gives a *winter balance* of 2.4 ±0.2 m w.eqv., corresponding to a water volume of 115±10 mill. m^3. The result is the same as the average for the period 1962-2001. Excluding the additional ablation in late autumn 2001 does not alter the result. Thus, the *winter accumulation* was also 2.4 m water equivalent.

The winter balance was also calculated using a gridding method based on the aerial distribution of the snow depth measurements (Fig. 3-3). In areas with insufficient measurements some (13) simulated points were extracted. These point values were modelled based on measurements from the period 1975-81, years with extensive measurements. Water equivalents for each cell in a 100 x 100 m grid were calculated and summarised. The result based on this method, which is a control of the traditional method, also showed a *winter balance* of 2.4 m w.eqv.

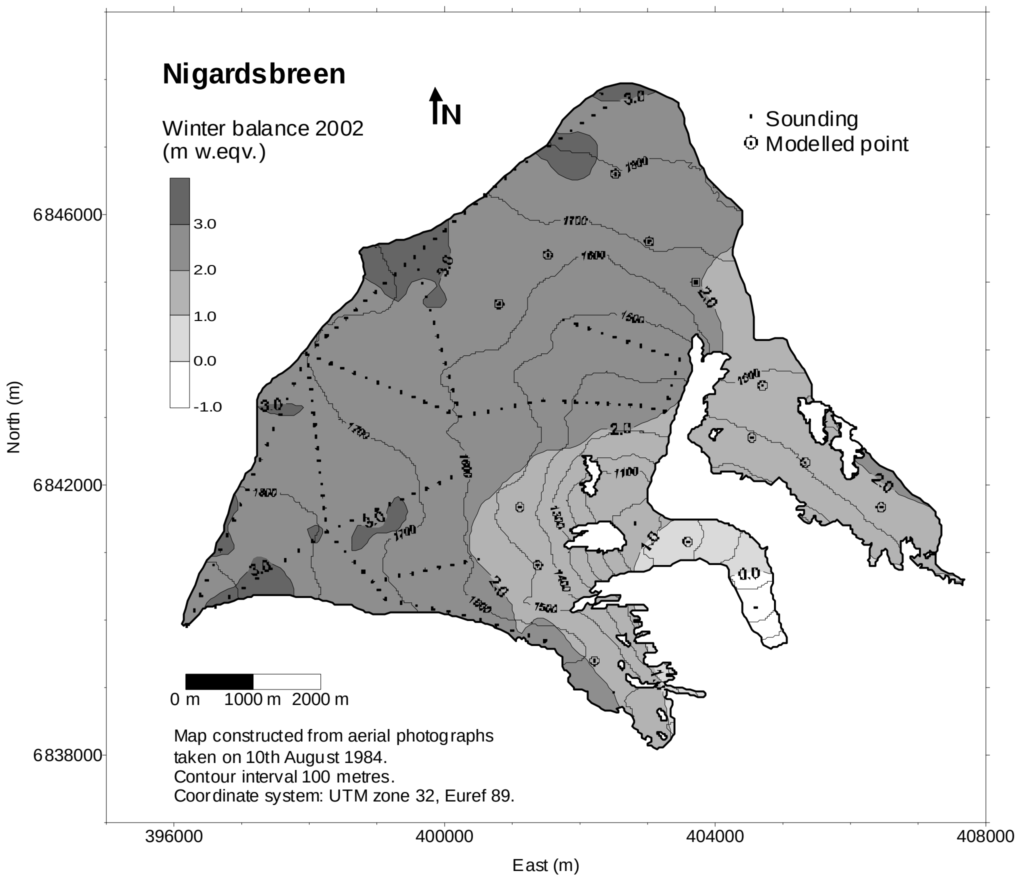


Figure 3-3
Winter balance at Nigardsbreen in 2002 interpolated from 162 measurements (•) of snow depth. In areas with few or no measurements 13 extrapolated points (◉) are added.

Summer balance

When calculating the summer balance the density of the remaining snow was estimated as 0.60 g/cm^3. The density of melted firn was estimated as 0.65 g/cm^3, and density of melted ice was determined as 0.90 g/cm^3.

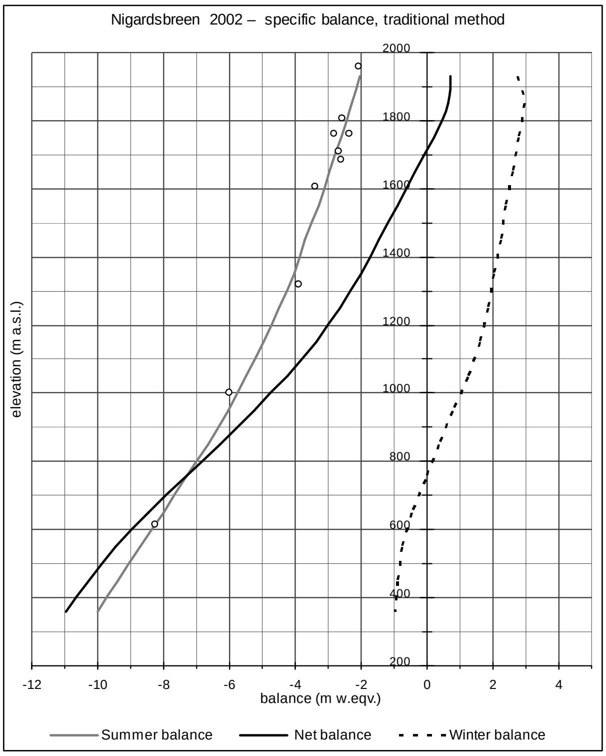
The summer balance was calculated at ten stakes and towers, and increased from about -2 m w.eqv. at the glacier summit to about -8 m down on the tongue. Based on estimated density and stake measurements the summer balance was calculated to be -3.3 ±0.3 m w.eqv., which is -158 ±15 mill. m^3 of water. The result is 173 % of the average for 1962-2001, and is the greatest summer balance measured since 1962.

Net balance

The net balance was calculated at stakes and towers in 11 positions. At stakes 600 and 1000 the measurements were supplemented with estimated data from previous years.

The net balance for 2002 was calculated as -0.9 m ±0.3 m w.eqv., which is equal to a deficit of 42 ±15 mill.m^3 water. The mean value for the period 1962-2001 is +0.48 m w.eqv. (Fig. 3-5), while the average over 1989-2001 is +0.97 m w.eqv.

The diagram in Figure 3-4 indicates that the equilibrium line altitude (ELA) was 1715 m a.s.l. Accordingly, the Accumulation Area Ratio (AAR) was 25 %.



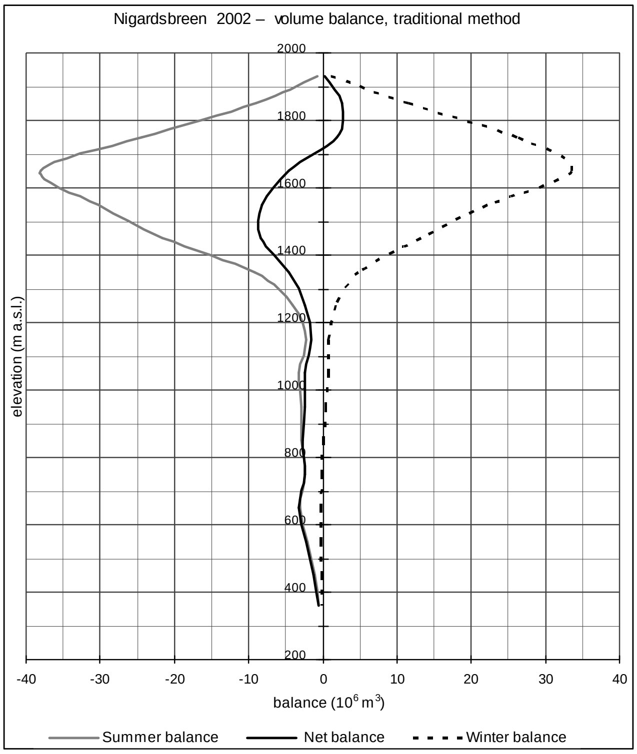


Figure 3-4
Mass balance diagram showing specific balance (left) and volume balance (right) for Nigardsbreen in 2002. Summer balance at ten stakes is shown as dots (○). The net balance curve intersects the y-axis and defines the ELA as 1715 m a.s.l. Thus the AAR was 25 %.

Mass balance Nigardsbreen 2001/02 – traditional method

Altitude (m a.s.l.)	Area (km^2)	Winter balance Measured 7th May 2002 Specific (m w.eq.)	Winter balance Volume (10^6 m^3)	Summer balance Measured 7th Oct 2002 Specific (m w.eq.)	Summer balance Volume (10^6 m^3)	Net balance Summer surface 2001 - 2002 Specific (m w.eq.)	Net balance Volume (10^6 m^3)
1900 - 1960	0,38	2,75	1,0	-2,05	-0,8	0,70	0,3
1800 - 1900	3,92	2,95	11,6	-2,30	-9,0	0,65	2,5
1700 - 1800	9,39	2,80	26,3	-2,60	-24,4	0,20	1,9
1600 - 1700	12,88	2,60	33,5	-2,95	-38,0	-0,35	-4,5
1500 - 1600	9,18	2,40	22,0	-3,30	-30,3	-0,90	-8,3
1400 - 1500	5,82	2,25	13,1	-3,70	-21,5	-1,45	-8,4
1300 - 1400	2,28	2,05	4,7	-4,05	-9,2	-2,00	-4,6
1200 - 1300	0,90	1,85	1,7	-4,50	-4,1	-2,65	-2,4
1100 - 1200	0,45	1,60	0,7	-4,95	-2,2	-3,35	-1,5
1000 - 1100	0,58	1,25	0,7	-5,50	-3,2	-4,25	-2,5
900 - 1000	0,47	0,80	0,4	-6,05	-2,8	-5,25	-2,5
800 - 900	0,44	0,35	0,2	-6,65	-2,9	-6,30	-2,8
700 - 800	0,33	-0,05	0,0	-7,35	-2,4	-7,40	-2,4
600 - 700	0,39	-0,45	-0,2	-8,00	-3,1	-8,45	-3,3
500 - 600	0,24	-0,75	-0,2	-8,70	-2,1	-9,45	-2,3
400 - 500	0,12	-0,90	-0,1	-9,40	-1,1	-10,30	-1,2
320 - 400	0,05	-0,95	0,0	-10,00	-0,5	-10,95	-0,5
320 - 1960	**47,82**	**2,41**	**115,3**	**-3,30**	**-157,8**	**-0,89**	**-42,5**

Table 3-1
Winter, summer and net balance for Nigardsbreen in 2002. Mean values for the period 1962-2001 are 2.40 (b_s), -1.92 m (b_s) and +0.48 m water equivalent (b_n).

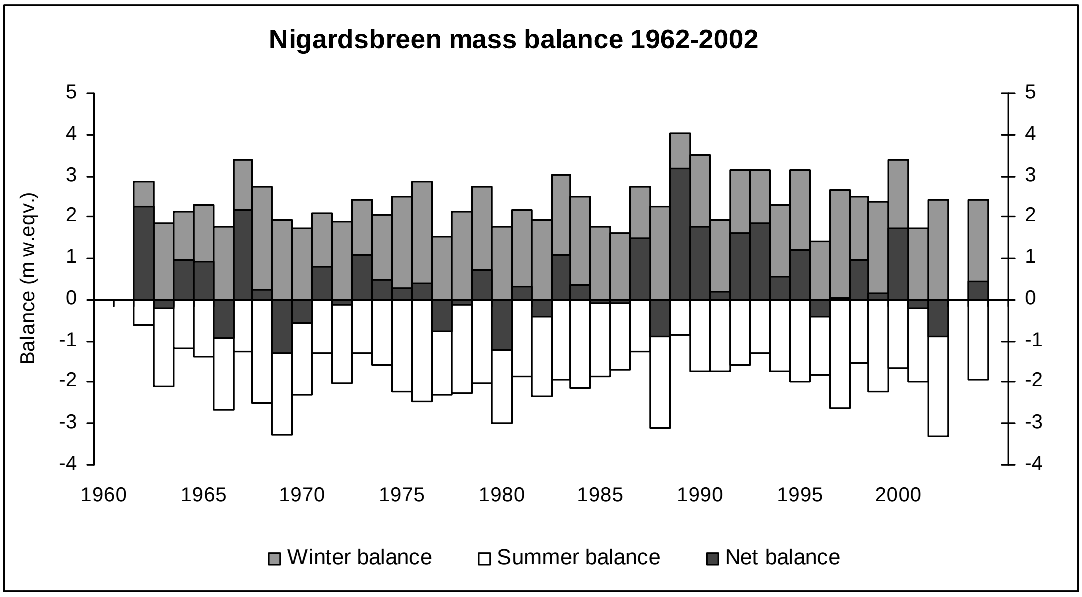


Figure 3-5
Annual mass balance at Nigardsbreen during the period 1962-2002.

3.2 Front position change

Recent years' changes of the glacier river persisted in 2002. The melt water was spread over several streams and rivers and the courses changed during the summer season. The main channel was located at the north-east side of the glacier snout (Fig. 3-6), but in the middle of October this river course was dry.

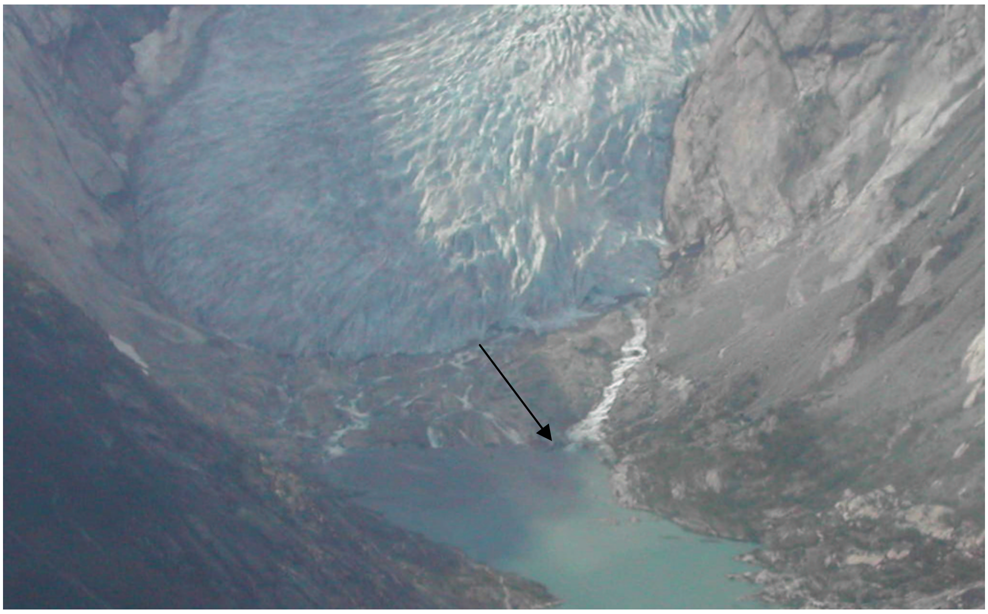


Figure 3-6
The glacier snout and the glacier streams photographed on 31st July 2002. At this time most of the melt water was running out at the north-east side of the glacier front (to the right). The front position measurements are carried out along an approximate straight line (marked with the arrow). Photo: Bjarne Kjøllmoen.

Change in front position is measured annually from fixed points along a defined straight line (Fig. 3-6). The measurement in October 2002 shows that the front position is approximately the same as in October 2001. However, visual observations indicate some advance at the south-west side of the glacier snout.

3.3 Tunsbergdalsbreen

Mass balance

From 1966 to 1972 mass balance measurements were made simultaneously at both Tunsbergdalsbreen (50.1 km^2, 1964) and Nigardsbreen. A linear regression analysis of the results from these seven years gives an equation that can be used to calculate the annual net balance of Tunsbergdalsbreen.

$$bn_T = 0.987 \cdot bn_N - 0.283$$

bn_T = net balance at Tunsbergdalsbreen, and bn_N = net balance at Nigardsbreen.

For 2002 the net balance at Tunsbergdalsbreen was estimated as -1.16 ±0.45 m w.eqv., corresponding to a deficit of about 55 mill. m^3 of water. Since 1962 the estimated accumulated net balance is about 6.5 m w.eqv.

Based on the measurements during 1966-72 a correlation between the equilibrium line altitude (ELA) for Nigardsbreen and Tunsbergdalsbreen was established. The analysis indicates that the ELA at Tunsbergdalsbreen in autumn 2002 was about 1600 m a.s.l.

Brimkjelen

About 3 km above the western side of the glacier snout lies an ice-dammed lake named Brimkjelen. Due to the glacier recession during the last century, the area and volume of the lake has decreased considerably. The last estimate of the volume was about 2 million m^3 in 1982.

From 1984 to 1997 no systematic observations were made of the lake. Annual observations was resumed in autumn 1997 and continued in 2002 by photographing on 7th of October. The lake was empty at this time and there were no indications of water in the lake during the last year.

4. Austdalsbreen (Hallgeir Elvehøy)

Austdalsbreen (61°45'N, 7°20'E) is an eastern outlet of the northern part of Jostedalsbreen, ranging in altitude from 1200 to 1760 m a.s.l. The glacier calves into the regulated lake Austdalsvatnet. Glaciological investigations started at Austdalsbreen in 1986 in connection with the construction of a hydroelectric power plant for which Lake Austdalsvatnet is a reservoir.

The glaciological investigations in 2002 included mass balance, front position change and glacier velocity. Mass balance has been measured on Austdalsbreen since 1988.

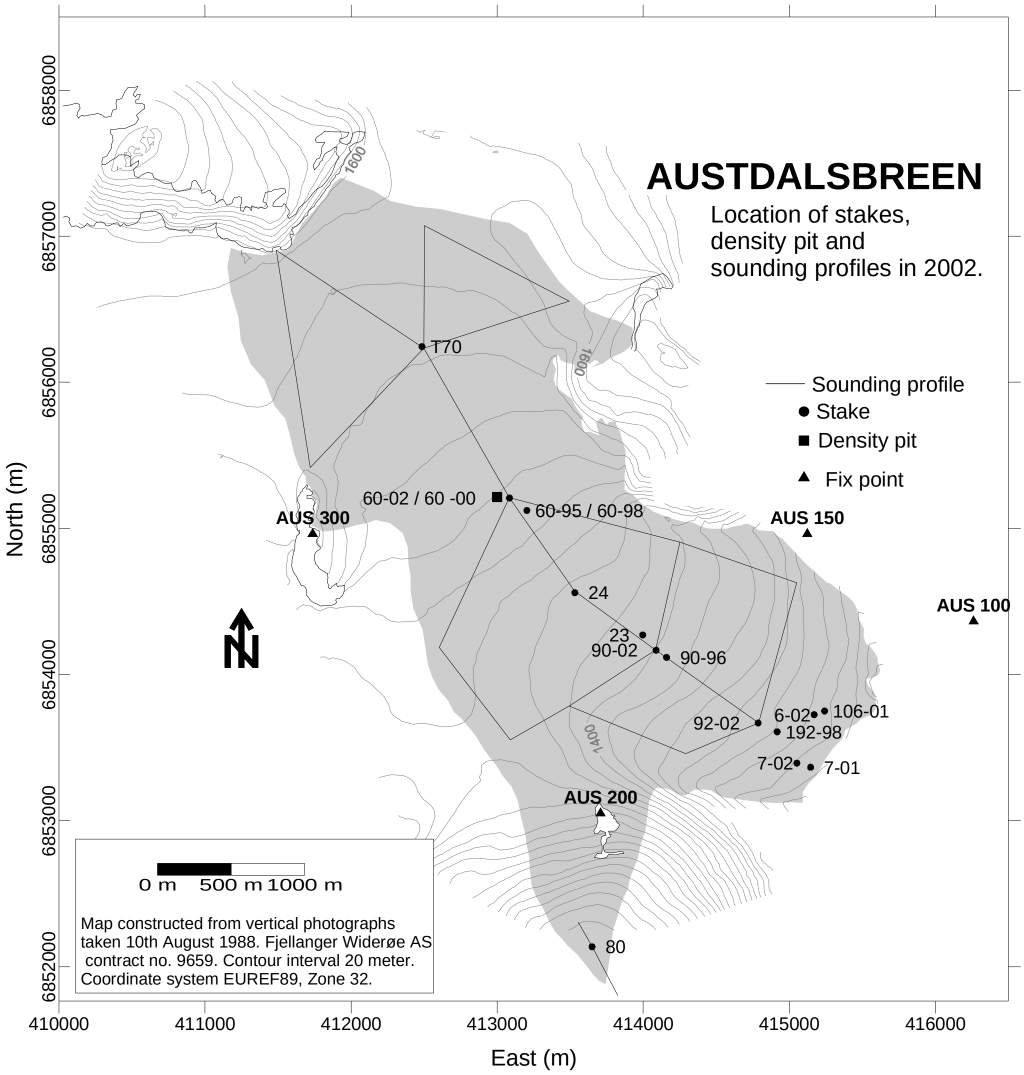


Figure 4-1
Location of stakes, density pits and sounding profiles at Austdalsbreen in 2002.

4.1 Mass balance 2002

Fieldwork

Winter accumulation was measured on 7th and 8th May. The calculation of winter balance was based on the following data (Fig. 4-1):

- Snow depth soundings at stake 7-01 (1235 m a.s.l.), 192-98 (1300 m a.s.l.), 90-96 (1400 m a.s.l.) and 23-87 (1410 m a.s.l.) showed snow depths of 1.95, 0.45, 3.10 and 3.25 m respectively. Comparison of snow depth soundings with change of stake length showed ice melt occuring after 20th September 2001 but before the start of snow accumulation at stakes 7-01 (0.55 m ice), 192-98 (0.35 m ice), 90-96 (0.10 m ice) and 23-87 (0.25 m ice).

- At T70 (1545 m a.s.l.) stake readings showed 4.95 m snow. Compaction of older firn between the SS from 2001 and the base of T70 (12 m below the SS) is approximately 0.15 m pr year, indicating a snow depth at this location of 5.1 m.

- Snow depth by coring on 14th March at stakes 90-02 (1400 m a.s.l.), 24-02 (1400 m a.s.l.) and 80-02 (1730 m a.s.l.) adjusted with change of stake length between 14th March and 8th May showing snow depth of 3.7, 4.5 and 3.8 m respectively.

- Coring at stakes 7-02, 6-02, 92-02 and 60-02 showing snow depths of 2.05, 1.65, 3.10 and 4.65 m, respectively.

- 90 snow depth measurements along 18 km of profiles. At Austdalsnuten above 1700 m a.s.l. the snow depth was 4 m. Between 1425 and 1600 m a.s.l. the snow depth was 4 to 5 m. Between 1300 and 1425 m a.s.l. the snow was 2.5 to 4 m deep, and below 1300 m a.s.l. the snow depth varied between 0 and 2 m. The summer surface from 2001 (SS) was easy to detect in all areas.

- Snow density down to SS at 4.65 m depth at stake 60-02 (1495 m a.s.l.). Mean snow density was 0.50 g/cm^3.

Summer ablation and net balance measurements were carried out on 7th October. All the winter snow had melted away at Austdalsbreen. Consequently, the transient snow line altitude (TSL) was higher than the top of the glacier (>1760 m a.s.l.). Several stakes melted out either between 8th May and 31st July or between 31st July and 9th October, while a number of older stakes reappeared from the snow pack. By comparison with neighbouring stakes the amount of melting at these stakes was estimated. At stake 80 (1730 m a.s.l.) 1 m of firn had melted away. At stakes between 1440 and 1600 m a.s.l. (24, 60 and T70) 1.5 to 0.8 m of firn had melted away. At stakes between 1300 and 1425 m a.s.l. (92, 90-96, 90-02 and 23) 3 to 4 m of ice had melted away. At the lowermost stakes (6-02, 7-01 and 7-02) 6 m of ice had melted away in addition to the winter snow cover.

Results

The mass balance was calculated according to the stratigraphic method (see chap.1). The calculations are based on a map from 10th August 1988 reduced for the areas below the highest regulated lake level (below 1200 m a.s.l., 0.11 km^2).

Winter balance

The winter balance was calculated as the sum of late autumn ablation and winter snow accumulation.

Late autumn ablation was calculated from stake readings on 20th September 2001 and 8th May 2002, and snow depth soundings on 8th May 2002. The late autumn ablation was registered at four stakes up to 1410 m a.s.l. The density of ice was set as 0.9 g/cm^3. The altitudinal distribution of the autumn ablation was then estimated over the entire glacier. In total, the late autumn melting was calculated as 0.1 m w.eqv., or 1.0 mill m^3 water.

The winter accumulation was calculated from snow depth and snow density measurements on 8th and 9th May. A function correlating snow depth with water equivalent was calculated based on snow density measurements at stake 60-02 (1495 m a.s.l.). The mean density of 5 m of snow in this profile was 0.50 g/cm^3. The profile was then used to convert all snow depth measurements to water equivalent.

Snow depth water equivalent values were plotted against altitude. By averaging of values within 50 m altitude intervals and visual evaluation, an altitudinal winter accumulation curve was drawn. Between 1600 and 1700 m a.s.l. no snow depths were measured, so the curve was interpolated in this area. Below 1300 m a.s.l. the snow depth varies greatly due to an irregular topography and crevasses which trap a large portion of the drifting snow. In this area the higher snow depth values are thought to be more representative. From the winter accumulation curve a mean value for each 50 m altitude interval was determined. The winter accumulation was 2.0 ±0.2 m w.eqv. or 24 ±2 million m^3 water.

The winter balance was also calculated using a gridding method based on the spatial distribution of the snow depth measurements (Fig. 4-2). Three extra points estimated from nearest measurements and terrain properties were included to support the interpolation routine. Water equivalents for each cell in a 25 x 25 m grid were calculated and summarised. The result based on this method, which is a control of the traditional method, also showed a winter accumulation of 2.0 m w.eqv.

The winter balance, including autumn ablation, was calculated as 1.9 ±0.2 m w.eqv. which corresponds to a volume of 23 ±2 million m^3 water. This is 83 % of the 1988 – 2001 average (2.31 m w.eqv.).

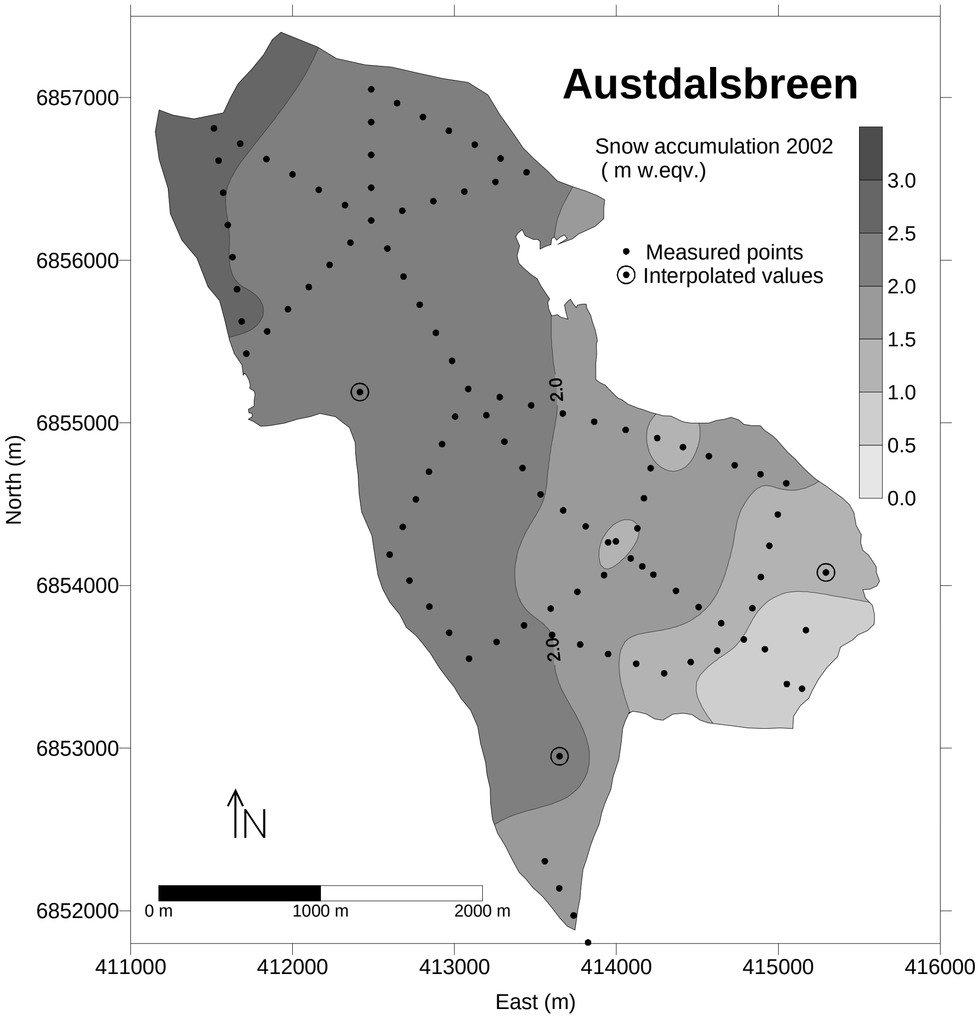


Figure 4-2
Winter accumulation at Austdalsbreen in 2002 from 93 water equivalent values calculated from snow depth soundings. Three estimated point values were added to aid the interpolation in areas without measurements.

Summer balance

The summer balance was calculated directly for five stake positions between 1245 and 1545 m. In addition, the summer balance was calculated for six stake positions where the stake had melted out during the summer season. A summer balance curve was drawn from these values (Fig. 4-3).

Calving from the glacier terminus was calculated as the annual volume of ice (in water equivalent) transported through a cross section close to the terminus, and adjusted for the volume change related to the annual front position change. This volume is calculated as:

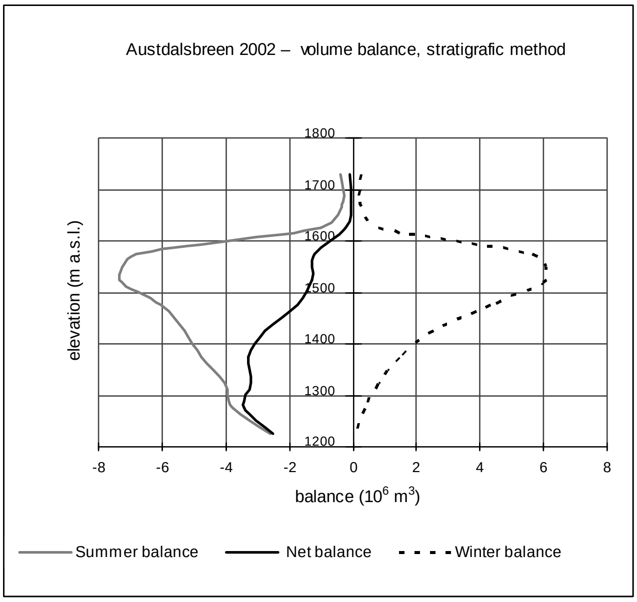
$$Q_k = \rho_{ice} * (u_{ice} - u_f) * W * H$$

where ρ_{ice} is 0.9 g/cm^3, u_{ice} is annual glacier velocity, 40 ±10 m/a (chapter 4.3), u_f is front position change averaged across the terminus, -48 ±5 m/a (chapter 4.2), W is terminus width, 1050 ±50 m, and H is mean ice thickness along the terminus, 48 ±5 m based on surface altitude surveyed September 2001 and October 2002, and a bottom topography map compiled from radar ice thickness measurements (1986), hot water drilling (1987) and lake depth surveying (1988 and 1989). This gave a calving volume of 4.0 ±0.5 million m^3 water or 0.35 ±0.04 m w.eqv. averaged across the glacier area (11.8 km^2).

The summer balance, including calving, was calculated as -3.9±0.3 m w.eqv., which corresponds to -46±3 million m^3 of water. The calving volume was 9 % of the summer balance. The result is 177 % of the 1988-2001 average of -2.21 m w.eqv.

Net balance

The net balance at Austdalsbreen was calculated as -2.0 ±0.3 m w.eqv., corresponding to -24 ±3 mill. m^3 water. The 1988-2001 average is +0.10 m w.eqv. The entire glacier was below the equilibrium line altitude (ELA). Consequently, the Accumulation Area Ratio (AAR) was 0 % for 2002. The altitudinal distribution of winter-, summer- and net balances are shown in Figure 4-3 and Table 4-1. Results from 1988-2002 are shown in Figure 4-4.



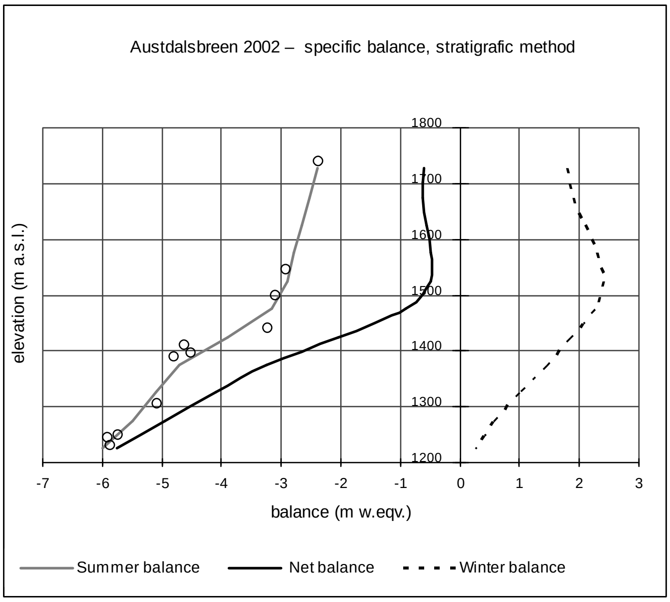


Figure 4-2
Altitudinal distribution of winter-, summer- and net balance shown as specific balance (left) and volume balance (right) at Austdalsbreen in 2002. Specific summer balance at seven locations is shown (o).

Mass balance Austdalsbreen 2001/02 – stratigrafic method

Altitude (m a.s.l.)	Area (km²)	Winter balance, Measured 8th May 2002: Specific (m w.eqv.)	Winter balance: Volume (10^6 m³)	Summer balance, Measured 7th Oct 2002: Specific (m w.eqv.)	Summer balance: Volume (10^6 m³)	Net balance, Summer surface 2001 - 2002: Specific (m w.eqv.)	Net balance: Volume (10^6 m³)
1700 - 1757	0,16	1,80	0,28	-2,40	-0,38	-0,60	-0,09
1650 - 1700	0,13	1,90	0,24	-2,53	-0,32	-0,63	-0,08
1600 - 1650	0,38	2,10	0,79	-2,66	-1,00	-0,56	-0,21
1550 - 1600	2,45	2,30	5,63	-2,79	-6,83	-0,49	-1,20
1500 - 1550	2,54	2,40	6,09	-2,90	-7,36	-0,50	-1,27
1450 - 1500	1,92	2,25	4,32	-3,15	-6,05	-0,90	-1,73
1400 - 1450	1,36	1,85	2,51	-3,90	-5,28	-2,05	-2,78
1350 - 1400	1,01	1,45	1,46	-4,70	-4,75	-3,25	-3,28
1300 - 1350	0,79	1,00	0,79	-5,10	-4,01	-4,10	-3,23
1250 - 1300	0,69	0,55	0,38	-5,50	-3,78	-4,95	-3,40
1200 - 1250	0,44	0,25	0,11	-6,00	-2,61	-5,75	-2,50
Calving					-4,0		-4,0
1200 - 1757	**11,84**	**1,91**	**22,6**	**-3,92**	**-46,4**	**-2,01**	**-23,8**

Table 4-1
Altitudinal distribution of winter-, summer- and net balances at Austdalsbreen in 2002.

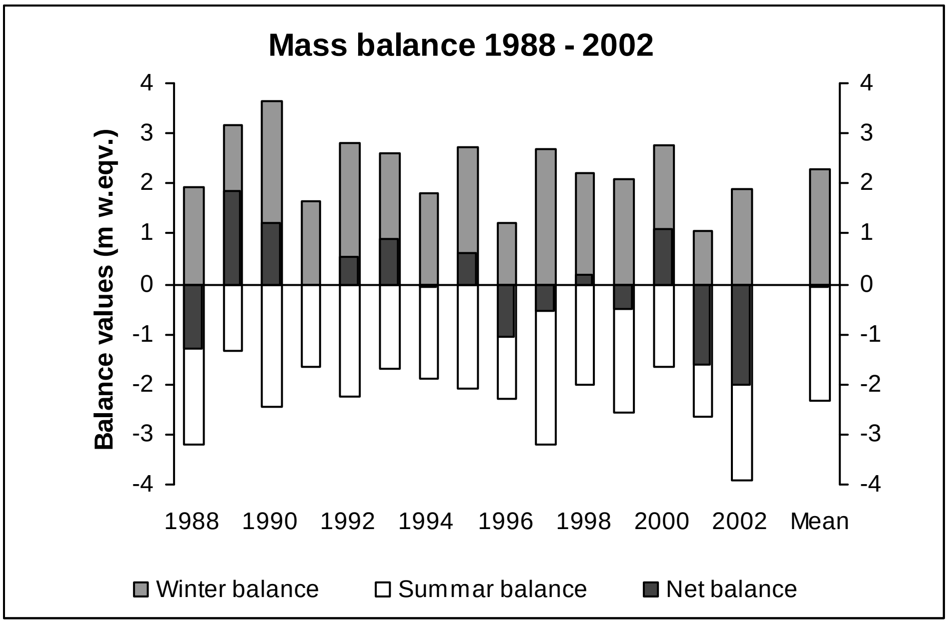


Figure 4-3
Winter-, summer and net balances at Austdalsbreen during the period 1988-2002.

4.2 Front position change

Four points along the terminus were surveyed on 7th October 2002. Between 20th September 2001 and 7th October 2002 the mean front position change was -48 ±5 m (Fig. 4-4). This is the largest annual retreat since 1990. Since 1988 the glacier terminus has retreated approximately 350 metres, while the glacier area is reduced by 0.36 km². The lower part of Austdalsbreen is shown in Figure 4-5.

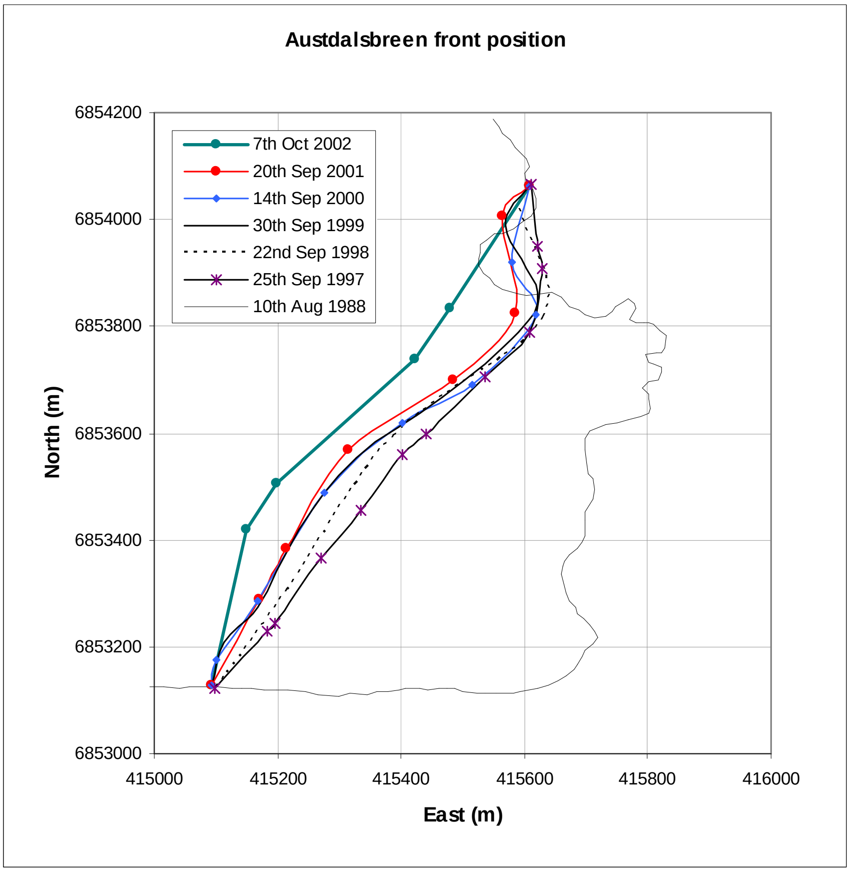


Figure 4-4
Surveyed front position at Austdalsbreen in 1988, 1997, 1998, 1999, 2000, 2001 and 2002. Mean front position retreat between 20th September 2001 and 7th October 2002 was -48 m.

Figure 4-5
Austdalsbreen 31st July 2002 as seen from fixed point AUS100 (Fig. 4-1).
Photo: Bjarne Kjøllmoen.

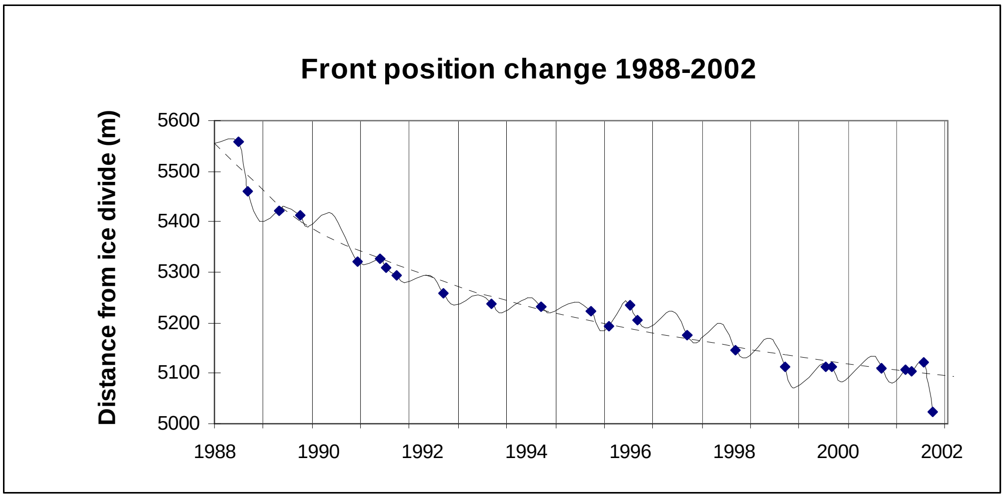


Figure 4-6
Surveyed front position change along a central flow line, shown as change in glacier length along this flow line (dots). The solid line indicates annual variation in front position. The glacier advances from December to July when the lake is frozen, and retreats during July-December due to calving. In 1988 the level of lake Austdalsvatnet was regulated as a reservoir for the first time. The broken line shows predicted front position change based on expected annual lake level variations due to regulation and an annual net balance of -0.47 m w.eqv. (Laumann & Wold, 1992).

Due to large variations in calving, the variation in front position throughout the year is large compared to the net change from year to year. Figure 4-6 illustrates how the front position at a central flow line has varied over the last 14 years. As a consequence of lake regulation it was expected that the glacier terminus would retreat. A modelling effort resulted in a prediction for future front position change shown as a broken line in Figure 4-6. Mean annual net balance has been -0.04 m w.eqv., while the model input used -0.47m w.eqv. This implies that calving has been more pronounced than modelled.

4.3 Glacier velocity

Glacier velocities are calculated from repeated surveys of stakes on the lower part of the glacier. The stake network was surveyed in September, March, May, July and October, and annual velocities were calculated for 8 stake positions. Above 1300 m a.s.l. there was very little change in glacier velocities between 2001 and 2002. At the stakes close to the terminus there was a drastic reduction in glacier velocity. The results are compared with results from 1988-2001 in Figure 4-7.

To calculate the calving volume (chapter 4.1) we estimate the glacier velocity averaged across the front width and thickness. The surface centre line velocity is calculated from measurements at stake 106-01 and 7-01 (53 m/a and 57 m/a), distance from stake to terminus (September and October), and calculated strain rate between stakes 106 and 7, and stake 92 (0.01 a^{-1}). The cross-sectional averaged glacier velocity is estimated to be 70 % of the centre line surface velocity based on earlier measurements and estimates of the amount of glacier sliding at the bed. This results in a terminus cross-sectional averaged glacier velocity of 40 ±10 m/a. Compared with

2001 when the calculated velocity was 60 m/a, the glacier has slowed down considerably.

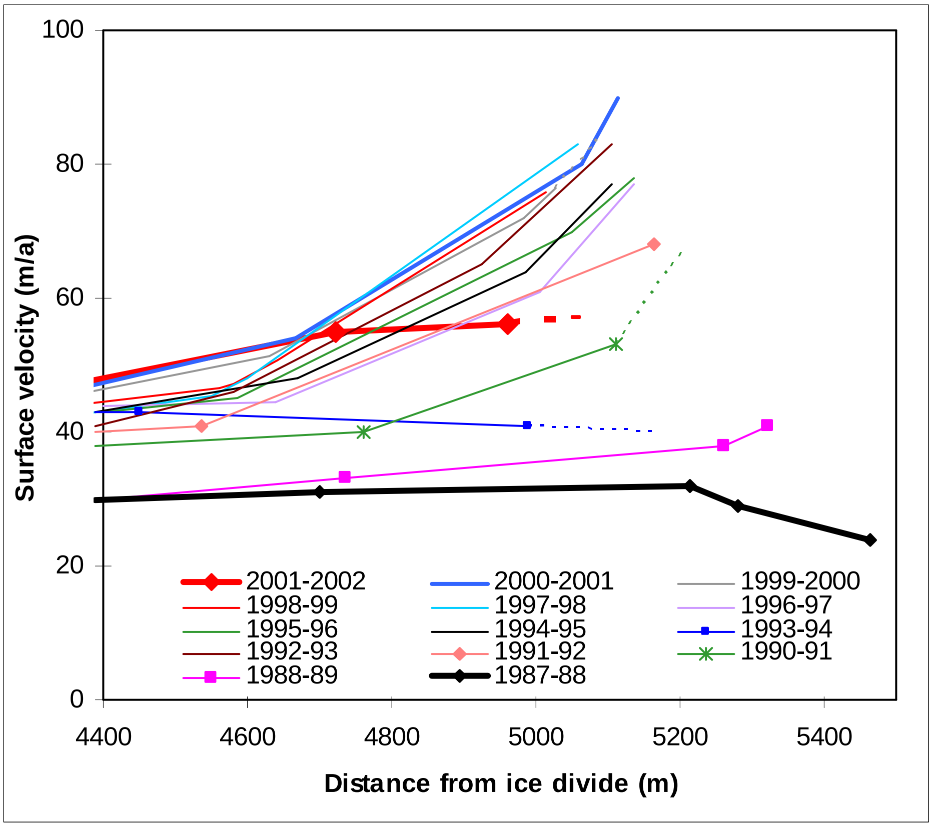


Figure 4-7
Glacier velocity (in m/a, September-September) along a central flow line interpolated between averaged stake positions at the lower part of the glacier. Between the lowest stake and the terminus the velocity is extrapolated (broken line). The distance 4600 m from ice divide corresponds approximately to stake 192 (Fig. 4-1). Between 1988 and 2002 the terminus retreated 450 metres along the flow line.

5. Hardangerjøkulen (Hallgeir Elvehøy)

Hardangerjøkulen (60°32'N, 7°22'E) is the sixth largest (73 km^2) glacier in Norway. The glacier is situated on the main water divide between Hardangerfjorden and Hallingdalen valley. In 1963 the Norwegian Polar Institute started mass balance measurements on the south-western outlet glacier Rembesdalskåka (17 km^2), which drains to Simadalen valley and Hardangerfjorden. This valley has been ravaged by jøkulhlaups from the glacier-dammed Lake Demmevatnet, the latest occurring in 1937 and 1938. Since 1985, the Norwegian Water Resources and Energy Directorate (NVE) has been responsible for the mass balance investigations at Rembesdalskåka. The investigated basin covers the altitudinal range between 1020 and 1865 m a.s.l.

Front position measurements were started at Midtdalsbreen by the University of Bergen in 1982. Statkraft initiated front position measurements at Rembesdalskåka in 1995. These measurements are described in chapter 14.

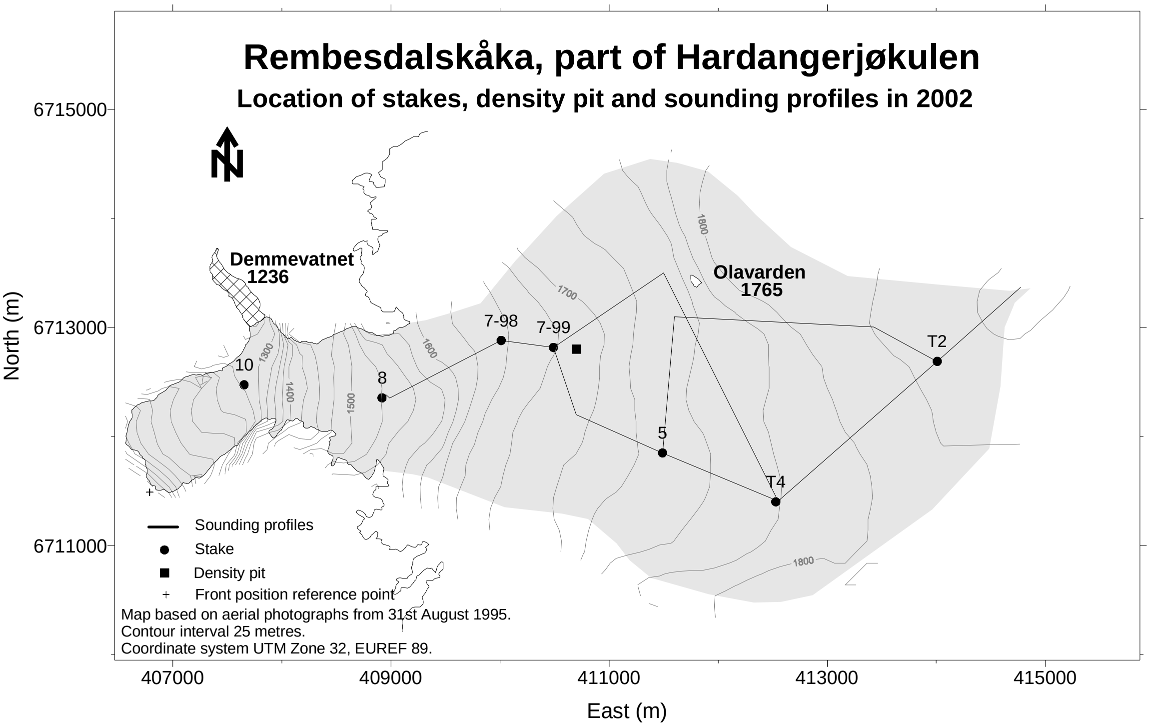


Figure 5-1
Location of stakes, density pit and sounding profiles at Rembesdalskåka, the south western outlet of Hardangerjøkulen, in 2002. The reference point for front position measurements is shown also.

5.1 Mass balance at Rembesdalskåka in 2002

Fieldwork

The winter balance was measured on 10th May. The calculation of winter balance is based on the following data (Fig. 5-1):

- Snow depth measurements at stakes 10 (1275 m a.s.l.), 8-99 (1520 m a.s.l.), 108-01 (1520 m a.s.l.), 7-98 (1645 m a.s.l.), 7-99 (1675 m a.s.l.), 5-02 (1725 m a.s.l.), T4 (1770 m a.s.l.) and T2 (1830 m a.s.l.) showing snow depths of 3.1, 2.9, 3.0, 3.85, 4.85, 4.85, 5.3 and 5.1 m respectively.

- Snow density down to 4.85 m depth at stake 7-99 (1675 m a.s.l.). Mean snow density was 0.50 g/cm^3. Below the SS at 4.85 m depth there was firn.
- 47 snow depth soundings along 11 km of profiles on the glacier plateau above 1500 m a.s.l. Between 1500 and 1700 m a.s.l. the snow depth was 3 to 5 m. Above 1700 m a.s.l. the snow depth was 4 to 6 m. The SS was fairly easy to detect. In addition, 19 snow depth soundings along 3 km of profiles between stake T2, Olavarden and stake 5-02 from 19th March was used in the calculations. These measurements were adjusted to 10th May using measured change at stake T2, T4 and 5.

Summer ablation and net balance was measured on 23rd September. There was fresh snow on the glacier above 1500 m a.s.l. Measurements at the stakes showed the new snow was up to 0.15 m deep. The transient snow line (TSL) could not be detected, but the TSL altitude was probably approximately 1750 m a.s.l. The net balance was measured at five locations between 1525 and 1830 m a.s.l. At stakes T4 and T2, 0.45 m of snow remained. At stakes 7-99 and 7-98, 0.5 and 1.7 m of firn respectively had melted away. At stake 8, all the winter snow and 3.25 m of ice had melted away. At location 5 (1725 m a.s.l.), the stake had fallen over by 4th September, indicating that most of the 4.85 m of snow measured in May had melted away. Between 4th and 23rd September another 0.5 m of snow and firn melted away at this position. At location 10 on the glacier tongue (1275 m a.s.l.), the stake had melted out by 4th September, indicating at least 2½ m of ice melt. Between 4th and 23rd September another 0.75 m of ice melted away at this stake.

Results

The mass balance is calculated according to a stratigraphic method relating the net balance to the difference between two successive “summer surfaces”, excluding snow accumulation before the date of net balance measurements but also excluding ablation after net balance measurements. The calculations are based on a map from 1995.

Winter balance

The winter balance was calculated from measurements taken on 10th May 2002.

A snow depth - water equivalent profile for 10th May 2002 was calculated based on snow density measurements at 1675 m a.s.l.. The mean density of 5 m of snow in this profile was 0.50 g/cm^3. All snow depth measurements were transformed to water equivalents using this profile.

The snow depth, in water equivalent values, was plotted against altitude. By averaging values within 50 m altitude intervals and visual evaluation, an altitudinal winter balance curve was drawn (Fig. 5-2). Below 1500 m a.s.l. the only snow depth measurement was at stake 10. In this area the accumulation curve had to be extrapolated from measurements at stakes 10 and 8.

From the winter balance curve a mean value for each 50 m altitude interval was determined. The winter balance was 2.4 ±0.2 m w.eqv. or 41 ±3 mill. m^3 water. This is 113 % of the 1963 – 2001 average of 2.12 m w.eqv., and 105 % of the 1997 - 2001 average of 2.28 m w.eqv.

Summer balance

The summer balance was calculated for five stake positions between 1525 and 1830 m a.s.l. Stake 10 (1275 m a.s.l.) melted out during the summer, and measurements therefore give a minimum estimate only. However, a linear regression model between summer balance in the altitude intervals 1650-1700 and 1250-1300 implies that the summer balance at stake 10 was 6 m w.eqv., corresponding to 3 m of snow and 5 m of ice. Stake 5 had fallen over on 4th September. Comparison with stake 7-99 and T4 between 7th June and 23rd September implies that most of the winter snow at stake 5 had melted by 4th September, and that a further 0.3 m of firn had melted by 23rd September. From these seven point values the summer balance curve in Figure 5-2 was drawn.

The summer balance was calculated as -3.1 ±0.2 m w.eqv., corresponding to -53 ±3 mill. m^3 of water. This is 160 % of the 1963-2001 average, which is –1.93 m w.eqv., and 147 % of the 1997-2001 average of –2.11 m w.eqv.

Net balance

The net balance at Rembesdalskåka was calculated to -0.7 ±0.3 m w.eqv. or -12 ±5 mill. m^3 water. The 1963-2001 average is +0.19 m w.eqv., and the 1997-2001 average is +0.17 m. The ELA for 2002 determined from the net balance curve in Figure 5-2 is 1750 m a.s.l. The accumulation area ratio (AAR) was 47 %. The altitudinal distribution of winter-, summer- and net balances is shown in Figure 5-2 and Table 5-1. Results from 1963-2001 are shown in Figure 5-3.

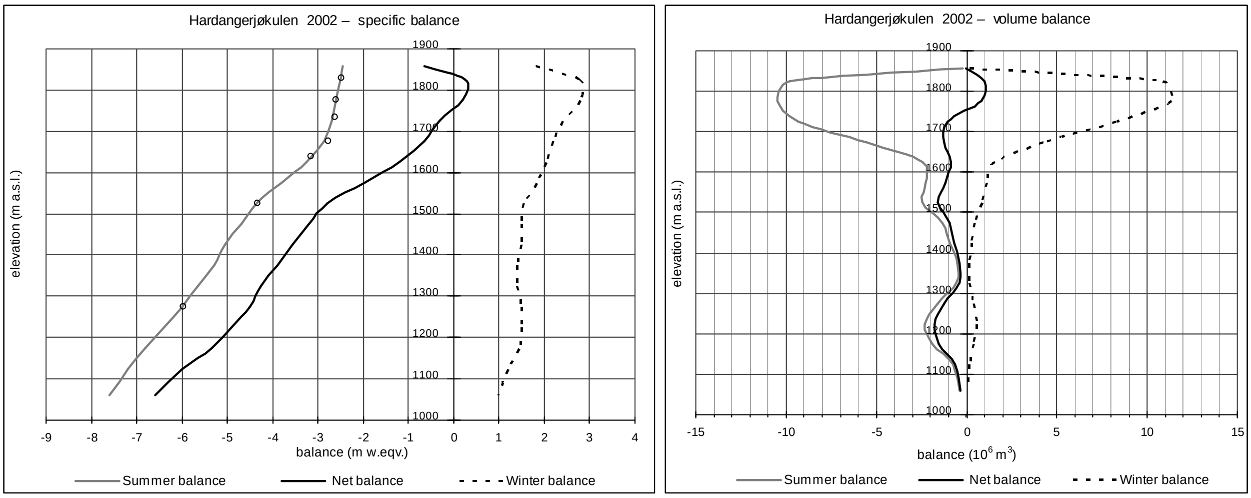


Figure 5-2
Altitudinal distribution of winter-, summer- and net balance shown as specific balance (left) and volume balance (right) at Rembesdalskåka, Hardangerjøkulen in 2002. Specific summer balance at seven locations is shown (o).

Mass balance Hardangerjøkulen 2001/02 – traditional method

Altitude (m a.s.l.)	Area (km^2)	Winter balance Measured 10th May 2001		Summer balance Measured 23rd Sep 2002		Net balance Summer surface 2001 - 2002	
		Specific (m w.eqv.)	Volume (10^6 m^3)	Specific (m w.eqv.)	Volume (10^6 m^3)	Specific (m w.eqv.)	Volume (10^6 m^3)
1850 - 1865	0,09	1,80	0,2	-2,45	-0,2	-0,65	-0,1
1800 - 1850	3,93	2,75	10,8	-2,50	-9,8	0,25	1,0
1750 - 1800	4,03	2,80	11,3	-2,60	-10,5	0,20	0,8
1700 - 1750	3,46	2,40	8,3	-2,70	-9,3	-0,30	-1,0
1650 - 1700	1,94	2,20	4,3	-2,85	-5,5	-0,65	-1,3
1600 - 1650	0,75	2,05	1,5	-3,25	-2,4	-1,20	-0,9
1550 - 1600	0,59	1,84	1,1	-3,80	-2,3	-1,96	-1,2
1500 - 1550	0,57	1,55	0,9	-4,35	-2,5	-2,80	-1,6
1450 - 1500	0,29	1,50	0,4	-4,70	-1,4	-3,20	-0,9
1400 - 1450	0,19	1,50	0,3	-5,05	-1,0	-3,55	-0,7
1350 - 1400	0,10	1,40	0,1	-5,30	-0,5	-3,90	-0,4
1300 - 1350	0,10	1,40	0,1	-5,65	-0,6	-4,25	-0,4
1250 - 1300	0,27	1,50	0,4	-6,00	-1,6	-4,50	-1,2
1200 - 1250	0,36	1,50	0,5	-6,40	-2,3	-4,90	-1,8
1150 - 1200	0,28	1,45	0,4	-6,80	-1,9	-5,35	-1,5
1100 - 1150	0,11	1,20	0,1	-7,20	-0,8	-6,00	-0,6
1020 - 1100	0,05	1,00	0,1	-7,60	-0,4	-6,60	-0,3
1020 - 1865	17,1	2,39	40,9	-3,10	-53,0	-0,71	-12,1

Table 5-1
Altitudinal distribution of winter-, summer- and net balances at Rembesdalskåka, Hardangerjøkulen in 2002.

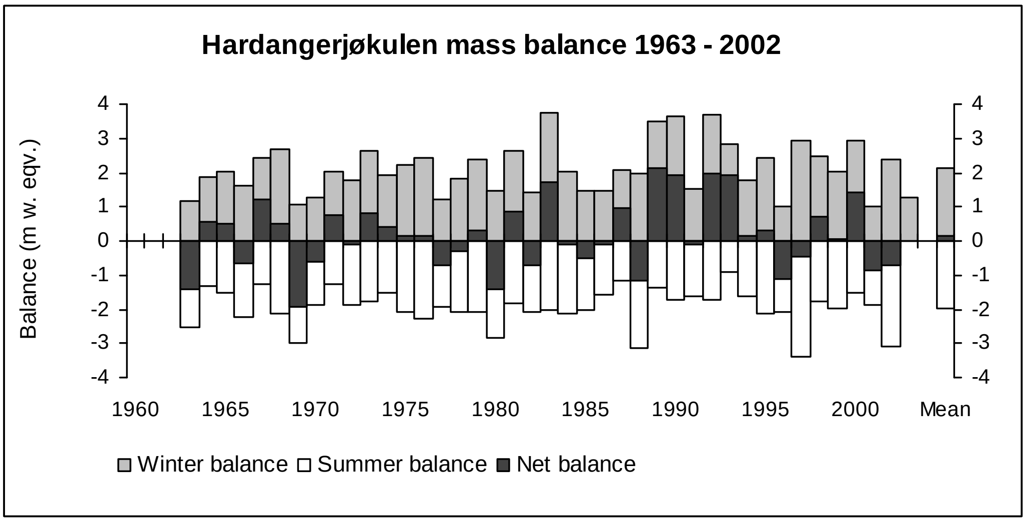


Figure 5-3
Winter-, summer- and net balances at Hardangerjøkulen during the period 1963-2002. Mean values for the period are b_w=2.13 m, b_s=-1,96 m and b_n=+0.16 m water equivalent.

6. Storbreen (Liss M. Andreassen and Laila P. Høivik)

Storbreen (61°34' N, 8°8' E) is situated in the Leirdalen valley in the central part of Jotunheimen, a mountainous area in central southern Norway (Fig. 6-1). The glacier has a total area of 5.4 km^2 and ranges in altitude from 1390 to 2090 m a.s.l. (Fig. 6-2). Mass balance measurements were initiated in 1949 and have been carried out continuously since then.

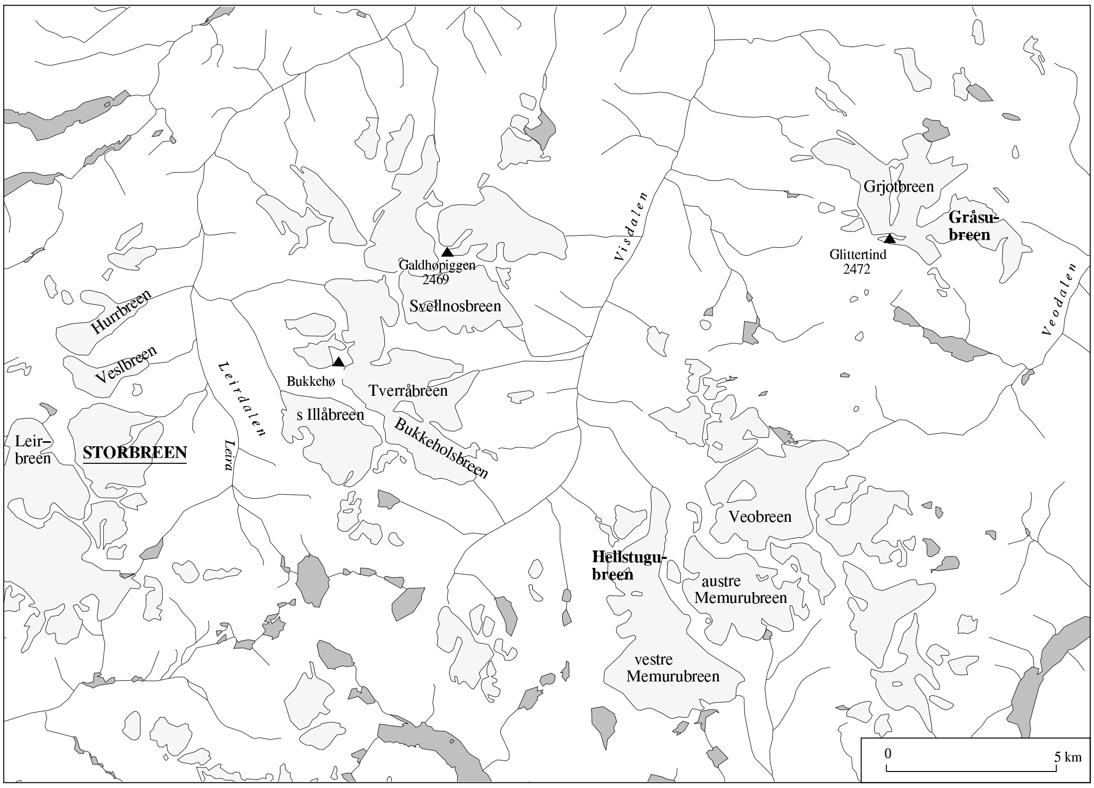


Figure 6-1
Location map showing Storbreen and other glaciers in the mountain area Jotunheimen. Mass balance measurements are carried out on Storbreen and Hellstugubreen in the central part and on Gråsubreen in the eastern part.

6.1 Mass balance 2002

Fieldwork

Accumulation measurements were performed on 7th May. Stakes were visible at five different locations. Two new stake positions were established (stakes 8 and 9, Fig. 6-2). Snow depth was measured at 132 points along 13 km of profiles, covering almost the whole elevation range of the glacier (Fig. 6-2). The probing conditions were good, and the summer surface from the previous year was easy to identify. Snow depth varied between 1.4 and 5.2 m, with a mean of 3.1 m.

Snow density was measured at stake 4 (1730 m a.s.l., Fig. 6-2) by sampling in a 3.2 m deep pit. Ablation measurements were performed on 20th September. Ablation or net balance was measured from at 9 stake locations.

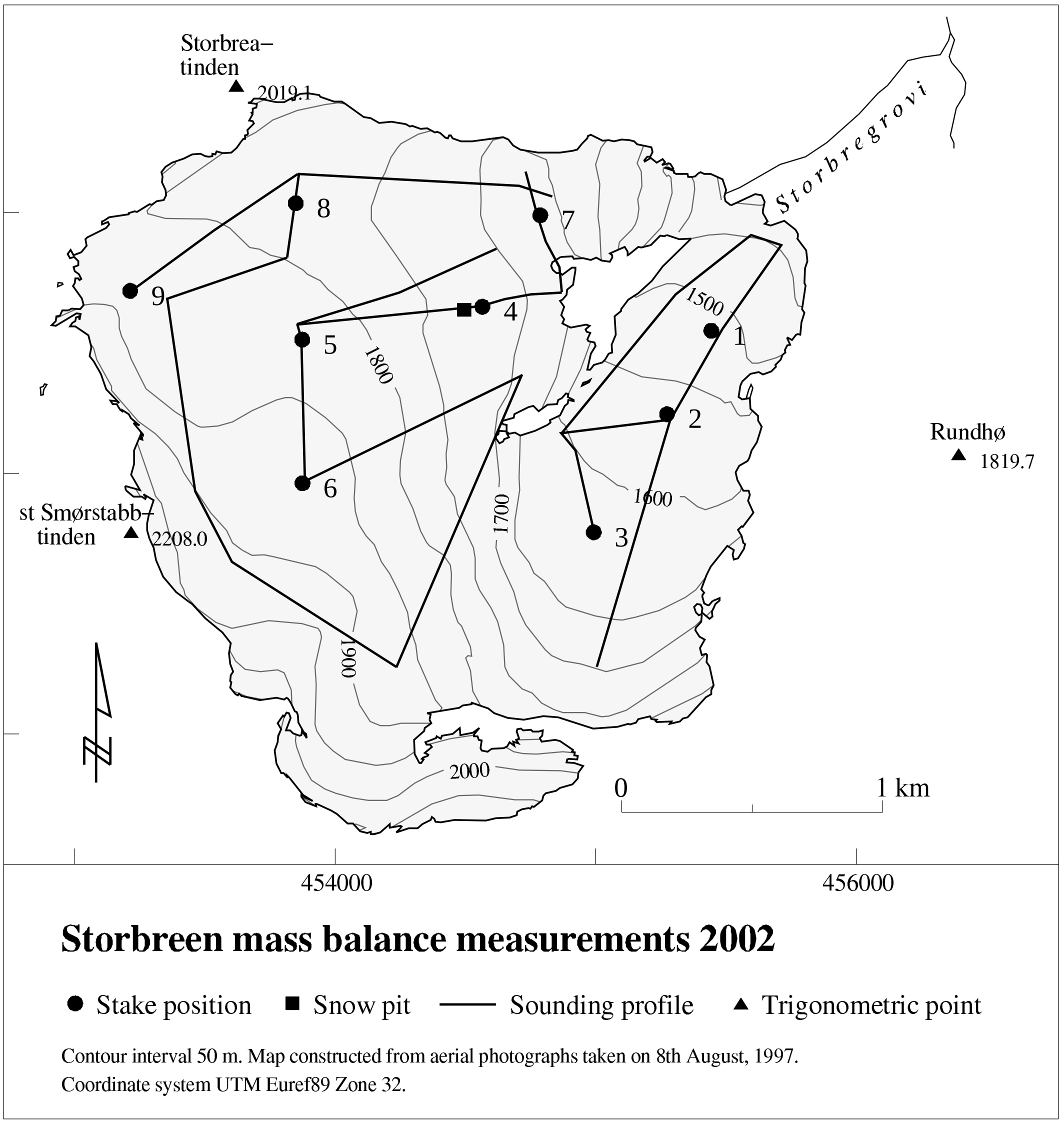


Figure 6-2
Map of Storbreen showing the mass balance programme in 2002.

Results

The collected mass balance results are shown in Table 6-1 and Figure 6-4.

Winter balance

Winter accumulation was calculated from soundings and the snow density measurements. The additional melting that occurred after the ablation measurements in 2001 was accounted for in the 2002 mass balance calculations.

The mean measured snow density was 0.41 g/cm^3. The density profile was considered to be representative for the rest of the glacier. The winter accumulation was calculated by plotting the mean of the soundings within each 50-metre height interval against altitude. This gave a winter accumulation of 1.2 m w.eqv. The additional melting after the ablation measurements the previous year was calculated from stake recordings, giving an average melt of 0-0.28 m w.eqv. at each position. Above 1950 m a.s.l. there was no additional melting.

The winter balance was calculated by subtracting the extra melt from the winter accumulation. The specific winter balance, including additional melting, was thus calculated to be 1.1 ± 0.2 m w.eqv. This is 75 % of the mean for the period 1949-2001.

Summer balance

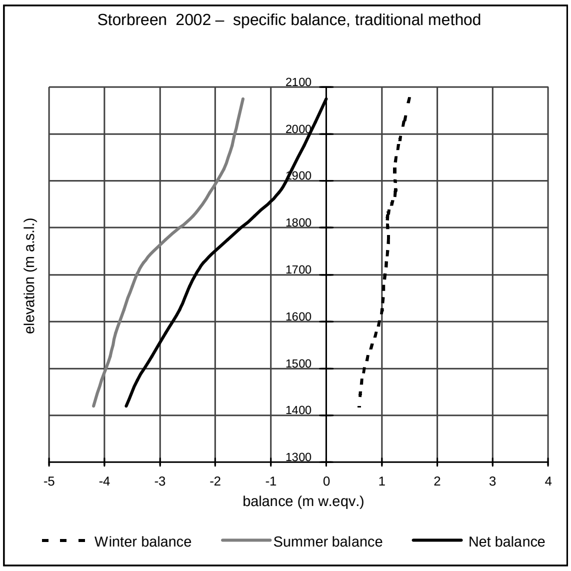
Summer balance was calculated directly from stakes in six locations and indirectly by net balance at three other locations. The density of the remaining snow was assumed to be 0.6 g/cm^3, based on measurements from previous years. The density of the melted ice was estimated to be 0.9 g/cm^3. The summer balance was calculated to be –2.9 ± 0.2 m w.eqv, which is 173 % of the mean for the period 1949-2001. This is the highest ablation ever measured at Storbreen over this period.

Figure 6-3
View from stake 7 on Storbreen September 2002. A layer of fresh snow covers the glacier. Photo: Laila P. Høivik.

Net balance

Less winter snow than normal and record high ablation resulted in a high negative net balance of Storbreen in 2002, -1.8 ± 0.3 m w.eqv., which is equivalent to a volume of 9.6 ± 0.16 10^6 m^3 of water. This is the most negative mass balance ever measured at Storbreen. The snow that accumulated during the winter all melted during the summer and at the end of the ablation season the ELA was above the glacier's maximum altitude. Thus, the accumulation area ratio (AAR) was 0 % in 2002.

The total deficit of the glacier since 1949 amounts to -12.5 m w.eqv., giving a mean annual net balance of -0.20 m w.eqv. (Fig. 6-5).



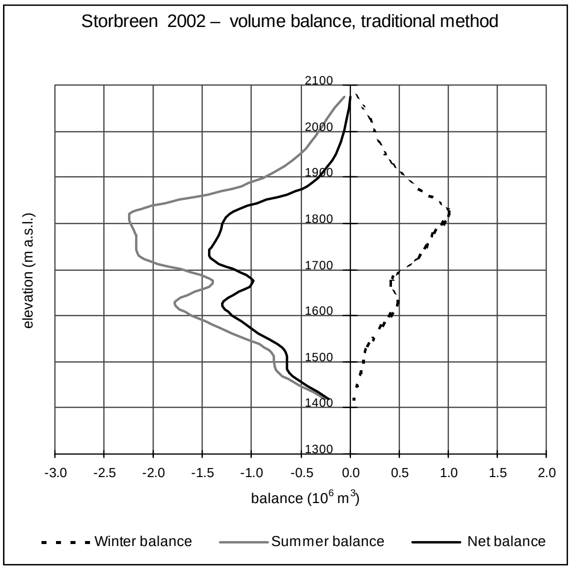


Figure 6-4
Mass balance diagram for Storbreen 2002, showing specific balance on the left and volume balance to the right.

Mass balance Storbreen 2001/02 – traditional method

Altitude (m a.s.l.)	Area (km^2)	Winter balance Measured 6 May 2002 Specific (m w.eq.)	Winter balance Volume (10^6 m^3)	Summer balance Measured 20 Sep 2002 Specific (m w.eq.)	Summer balance Volume (10^6 m^3)	Net balance Summer surfaces 2001 - 2002 Specific (m w.eq.)	Net balance Volume (10^6 m^3)
2050 - 2100	0.04	1.50	0.06	-1.50	-0.06	0.00	0.00
2000 - 2050	0.15	1.40	0.21	-1.60	-0.24	-0.20	-0.03
1950 - 2000	0.23	1.30	0.30	-1.70	-0.39	-0.40	-0.09
1900 - 1950	0.36	1.23	0.44	-1.85	-0.67	-0.62	-0.22
1850 - 1900	0.57	1.25	0.71	-2.10	-1.20	-0.85	-0.49
1800 - 1850	0.92	1.11	1.02	-2.40	-2.21	-1.29	-1.19
1750 - 1800	0.75	1.12	0.84	-2.90	-2.18	-1.78	-1.33
1700 - 1750	0.64	1.09	0.69	-3.30	-2.11	-2.22	-1.42
1650 - 1700	0.40	1.04	0.41	-3.50	-1.40	-2.46	-0.99
1600 - 1650	0.49	1.01	0.49	-3.65	-1.79	-2.64	-1.30
1550 - 1600	0.35	0.90	0.32	-3.80	-1.33	-2.90	-1.01
1500 - 1550	0.21	0.75	0.16	-3.90	-0.82	-3.15	-0.66
1450 - 1500	0.18	0.64	0.12	-4.05	-0.73	-3.41	-0.61
1390 - 1450	0.06	0.59	0.04	-4.20	-0.25	-3.61	-0.22
1390 - 2100	**5.35**	**1.09**	**5.81**	**-2.87**	**-15.37**	**-1.79**	**-9.56**

Table 6-1
The distribution of winter, summer and net balance in 50 m altitude intervals for Storbreen in 2002.

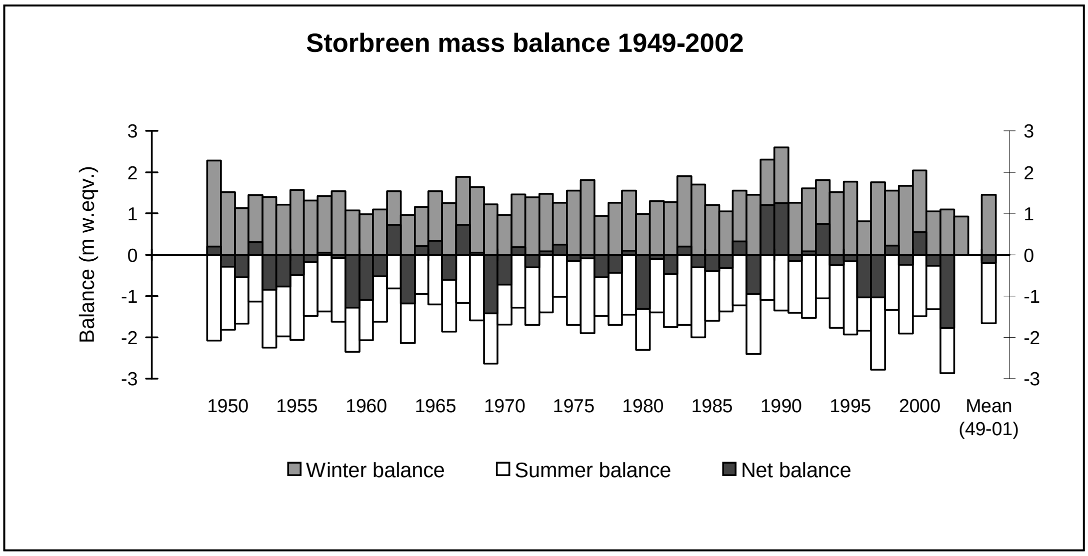


Figure 6-5
Winter, summer and net balance at Storbreen for the period 1949-2002.

6.2 Front position change

The front position of Storbreen was not measured in 2002.

7. Hellstugubreen (Liss M. Andreassen, Laila P. Høivik)

Hellstugubreen (61º34`N, 8º 26`E) is a north-facing valley glacier situated in central Jotunheimen (Fig. 6-1). It ranges in elevation from 1480 to 2210 m a.s.l. and has an area of 3.0 km^2 (Fig. 7-1). Mass balance investigations have been carried out annually since 1962.

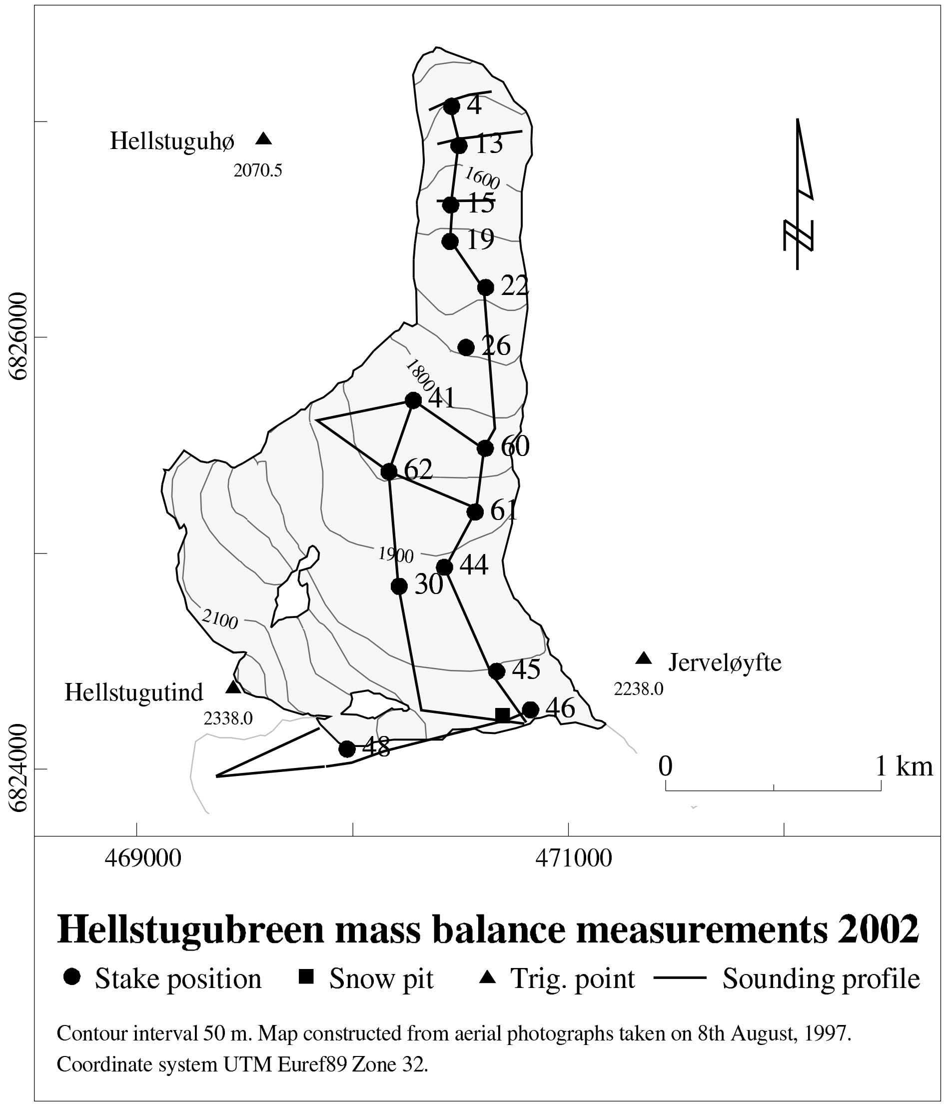


Figure 7-1
Map of Hellstugubreen showing the mass balance programme in 2002. Figure 6-1 shows a location map of the study glaciers in Jotunheimen.

7.1 Mass balance 2002

Fieldwork

Accumulation measurements were carried out on 8th May. Stakes at 12 locations were visible. Snow depth was measured at 96 points along 10 km of profiles covering most of the glacier (Fig. 7-1). The probing conditions were good, and the summer surface the previous year was easy to identify over the whole glacier. The snow depth varied between 0.7 and 4.6 metres, with a mean depth of 2.5 m. Nearly two thirds of the measurements were between 2 and 3 metres.

The snow density was measured by sampling in a pit at 1950 m a.s.l. The total snow depth was 2.8 m. Ablation measurements were carried out on 22nd September, on stakes at 15 locations. The location of stakes, density pit and sounding profiles are shown in Figure 7-1.

Figure 7-2
The upper part and the glacier front of Hellstugubreen on September 22nd.
Photo: Laila P. Høivik.

Results

The collected mass balance results are presented in Table 7-1 and Figure 7-3.

Winter balance

The winter balance was calculated from soundings and the snow density measurement, which was considered to be representative for the rest of the glacier. The winter accumulation was calculated by plotting the mean of the soundings within each 50-metre height interval against altitude, and drawing a representative curve. This gave a winter accumulation of 1.03 ± 0.2 m w.eqv. The additional melt after the previous year's ablation measurement was calculated from stake recordings, giving an extra melt of up to 0.2 w.eqv. The winter balance was calculated by subtracting the extra melt from the winter accumulation. The specific winter balance was thus calculated to be 0.96 ± 0.2 m w.eqv. This is 85 % of the mean for the period 1962-2001.

Summer balance

The summer balance was calculated from stakes at 15 locations. The density of the remaining snow was assumed to be 0.6 g/cm^3 and the density of the remaining firn to be 0.7 g/cm^3. The density of the melting ice was estimated to be 0.9 g/cm^3. The summer balance was calculated to be -2.4 ± 0.2 m w.eqv., which is 175 % of the mean value for the entire observation period and the second highest ablation measured in the observation period.

Net balance

The net balance of Hellstugubreen in 2002 was -1.41 ± 0.3 m w.eqv., which amounts to a lost volume of -4.3 ± 0.09 mill. m^3 water. The equilibrium line altitude (ELA) was 2080 m a.s.l. and the AAR was 7 % (Fig. 7-3). Since 1962 Hellstugubreen has had a cumulative mass loss of 12.0 m w.eqv., the equivalent of -0.26 m w.eqv. per year (Fig. 7-4).

Mass balance Hellstugubreen 2001/02 – traditional method

Altitude (m a.s.l.)	Area (km^2)	Winter balance Measured 5 May 2002 Specific (m w.eq.)	Winter balance Volume (10^6 m^3)	Summer balance Measured 22 Sep 2002 Specific (m w.eq.)	Summer balance Volume (10^6 m^3)	Net balance Summer surfaces 2001 - 2002 Specific (m w.eq.)	Net balance Volume (10^6 m^3)
2150 - 2210	0,02	1,00	0,02	-0,50	-0,01	0,50	0,01
2100 - 2150	0,09	1,06	0,10	-0,80	-0,07	0,26	0,02
2050 - 2150	0,28	1,16	0,33	-1,10	-0,31	0,06	0,02
2000 - 2050	0,18	1,20	0,22	-1,40	-0,26	-0,20	-0,04
1950 - 2000	0,38	1,16	0,44	-1,75	-0,66	-0,59	-0,22
1900 - 1950	0,61	1,07	0,65	-2,05	-1,25	-0,98	-0,60
1850 - 1900	0,35	1,02	0,35	-2,35	-0,81	-1,33	-0,46
1800 - 1850	0,33	0,91	0,30	-2,60	-0,85	-1,69	-0,55
1750 - 1800	0,13	0,77	0,10	-2,90	-0,39	-2,13	-0,28
1700 - 1750	0,10	0,79	0,08	-3,15	-0,33	-2,36	-0,25
1650 - 1700	0,17	0,81	0,14	-3,50	-0,59	-2,69	-0,45
1600 - 1650	0,13	0,66	0,08	-3,90	-0,49	-3,24	-0,41
1550 - 1600	0,16	0,46	0,07	-4,35	-0,69	-3,89	-0,62
1500 - 1550	0,08	0,16	0,01	-4,75	-0,37	-4,59	-0,36
1480 - 1500	0,02	-0,02	0,00	-5,00	-0,09	-5,02	-0,09
1480 - 2210	**3,03**	**0,96**	**2,90**	**-2,37**	**-7,18**	**-1,41**	**-4,28**

Table 7-1
The distribution of winter, summer and net balance in 50 m altitude intervals for Hellstugubreen in 2002.

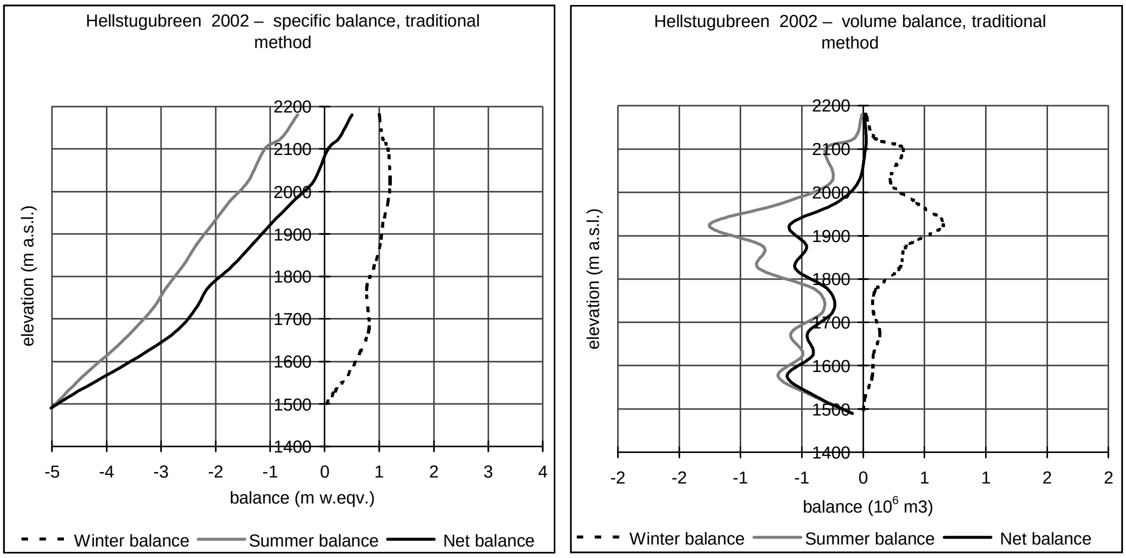


Figure 7-3
Mass balance diagram for Hellstugubreen 2002, showing specific balance on the left and volume balance on the right.

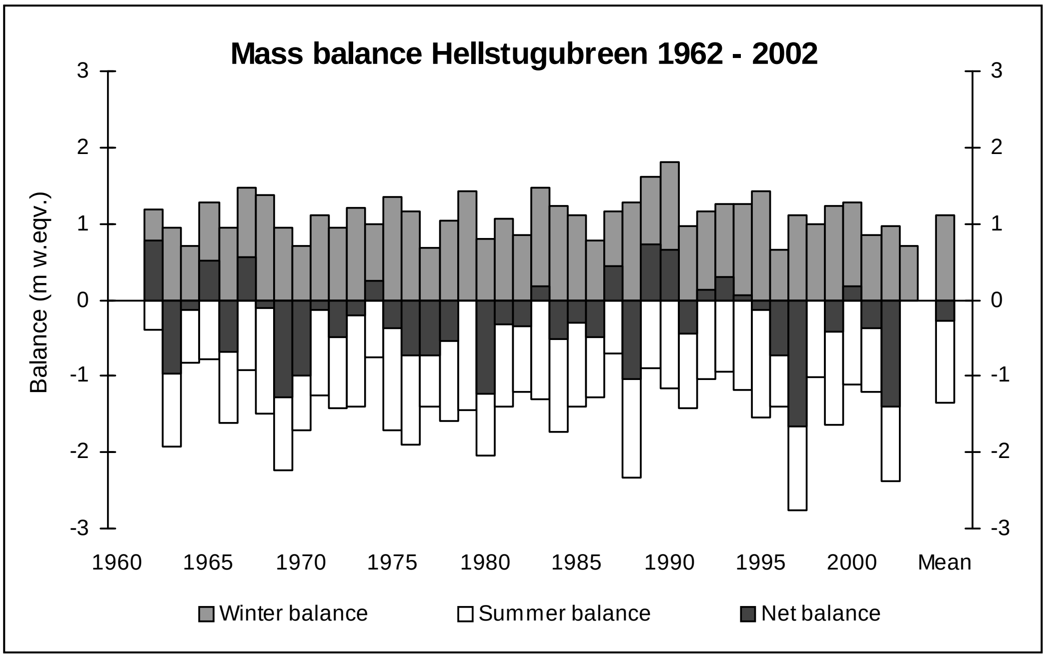


Figure 7-4
Winter, summer and net balance at Hellstugubreen for the period 1962-2002.

7.2 Front position change

The glacier front of Hellstugubreen had a net retreat of 17 metres from September 2001 to September 2002. The total retreat in front position is thus 1027 m since measurements began in 1901.

8. Gråsubreen (Liss M. Andreassen and Laila P. Høivik)

Gråsubreen (61°39' N, 8°37'E) is located in the eastern part of the Jotunheimen mountain area in southern Norway (Fig. 6-1). The glacier covers an area of 2.2 km^2 and ranges in elevation from 1830 to 2290 m a.s.l. (Fig. 8-1). Annual mass balance measurements began in 1962 and have continued annually since then.

Gråsubreen is a polythermal glacier. Superimposed ice occurs in the central parts of the glacier where snowdrift causes a relatively thin snow pack, and superimposed ice may be responsible for up to 8 % of the total accumulation in these areas.

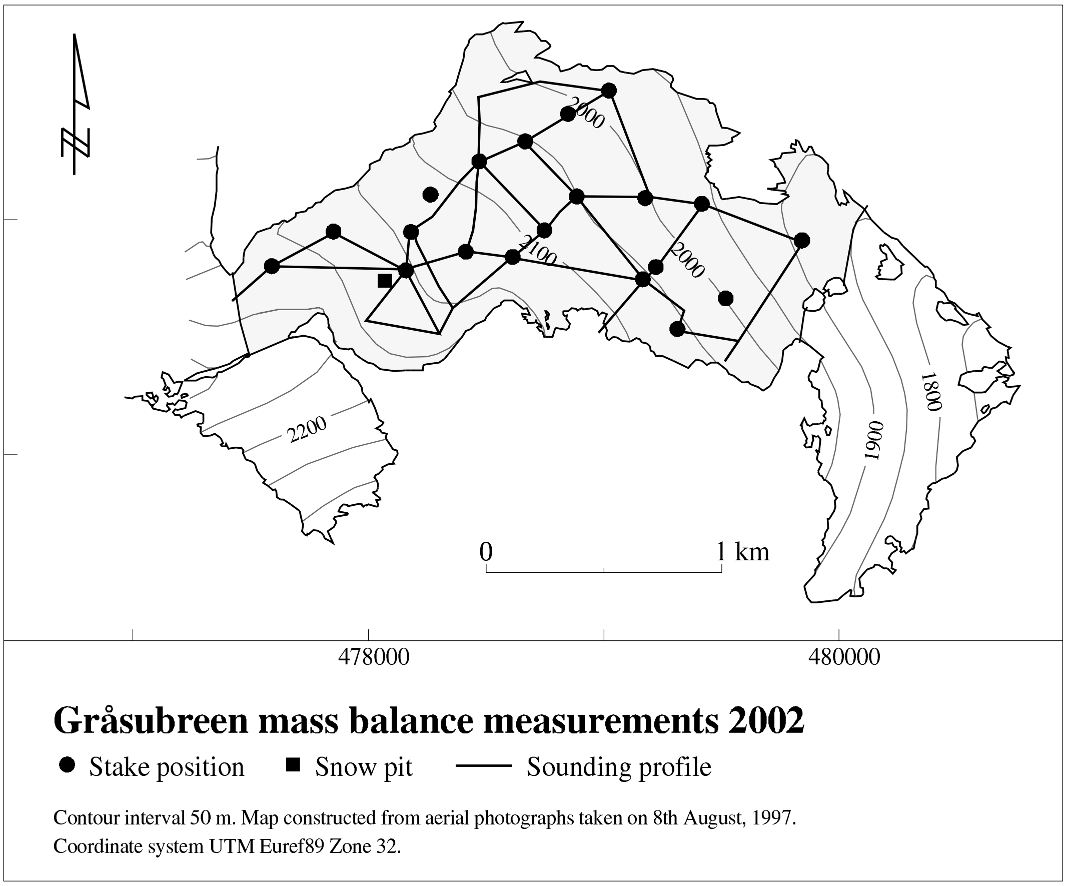


Figure 8-1
Map of Gråsubreen (shaded in grey) showing the mass balance programme in 2002. A location map of Gråsubreen and other glaciers in Jotunheimen is shown in Figure 6-1.

8.1 Mass balance 2002

Fieldwork

Accumulation measurements were carried out on 10th May. Stakes in 19 locations were measured. A total of 104 snow depth measurements were made along 11.6 km of profiles, covering most of the glacier (Fig. 8-1). The probing conditions were good, and the previous year's summer surface was easy to identify over the entire glacier. Snow depth varied between 0.5 and 2.9 m, with a mean of 1.5 m.

The snow density was measured at 2180 m a.s.l. in a pit dug through the winter snow pack (2.0 m snow). Ablation measurements were carried out on 25th September, when stakes in all locations were measured (Fig. 8-1).

Results

The collected mass balance results are presented in Table 8-1 and Figure 8-3.

Winter balance

Winter accumulation was calculated from the soundings and the snow density measurement, which was considered representative for the whole glacier. The mean measured snow density was 0.42 g/cm^3. The winter accumulation was calculated by plotting the mean of the soundings within each 50-meter height interval against altitude, and drawing a representative curve. This gave a winter accumulation of 0.63 m w.eqv.

In 2002 both additional melting after the previous year's ablation measurements and the formation of superimposed ice was measured from stake recordings, but the contribution to the net balance from each could not be determined separately. However, for the glacier as a whole the surplus of superimposed ice and the deficit of additional melting cancelled each other out. The specific winter balance was thus calculated to be 0.63 ± 0.2 m w.eqv., which is 82 % of the mean for the period 1962-2001.

Summer balance

Summer balance was calculated from direct measurements of stakes in 15 locations. The density of the remaining snow was assumed to be 0.6 g/cm^3. The density of the melted ice and firn was estimated to be 0.90 and 0.70 g/cm^3 respectively. The resulting summer balance was -2.05 ± 0.3 m w.eqv. This is 198 % of the mean for the period 1962-2001. This is the second largest summer balance recorded at Gråsubreen during the observation period.

Net balance

Gråsubreen had a pronounced mass loss in 2002 with a net balance of -1.4 ± 0.3 m w.eqv. The equilibrium line altitude (ELA) was above the maximum altitude of the glacier, thus the accumulation area ratio (AAR) was 0 % (Fig. 8-3).

Since 1962 there has been a cumulative mass loss of 11.3 m w.eqv. from Gråsubreen. Most of this mass loss occurred in the 1970s and 1980s. The mean of the period is -0.25 m w.eqv. (Fig 8-4).

Figure 8-2
Field work on Gråsubreen 25th September 2002. A fresh layer of snow has covered the surface. Photo: Laila P. Høivik.

Mass balance Gråsubreen 2001/02 – traditional method

Altitude (m a.s.l.)	Area (km^2)	Winter balance Measured 10 May 2002		Summer balance Measured 25 Sep 2002		Net balance Summer surfaces 2001 - 2002	
		Specific (m w.eq.)	Volume (10^6 m^3)	Specific (m w.eq.)	Volume (10^6 m^3)	Specific (m w.eq.)	Volume (10^6 m^3)
2250 - 2290	0.04	0.35	0.02	-0.70	-0.03	-0.35	-0.02
2200 - 2250	0.17	0.50	0.08	-1.05	-0.17	-0.55	-0.09
2150 - 2200	0.26	0.72	0.19	-1.55	-0.41	-0.83	-0.22
2100 - 2150	0.34	0.49	0.17	-2.00	-0.67	-1.51	-0.51
2050 - 2100	0.37	0.57	0.21	-2.20	-0.82	-1.63	-0.61
2000 - 2050	0.42	0.73	0.30	-2.30	-0.96	-1.57	-0.66
1950 - 2000	0.36	0.64	0.23	-2.35	-0.84	-1.71	-0.61
1900 - 1950	0.14	0.62	0.09	-2.40	-0.34	-1.78	-0.25
1830 - 1900	0.15	0.93	0.14	-2.40	-0.37	-1.47	-0.22
1830 - 2290	**2.25**	**0.63**	**1.43**	**-2.05**	**-4.62**	**-1.41**	**-3.19**

Table 8-1
The distribution of winter, summer and net balance in 50 m altitude intervals for Gråsubreen in 2002.

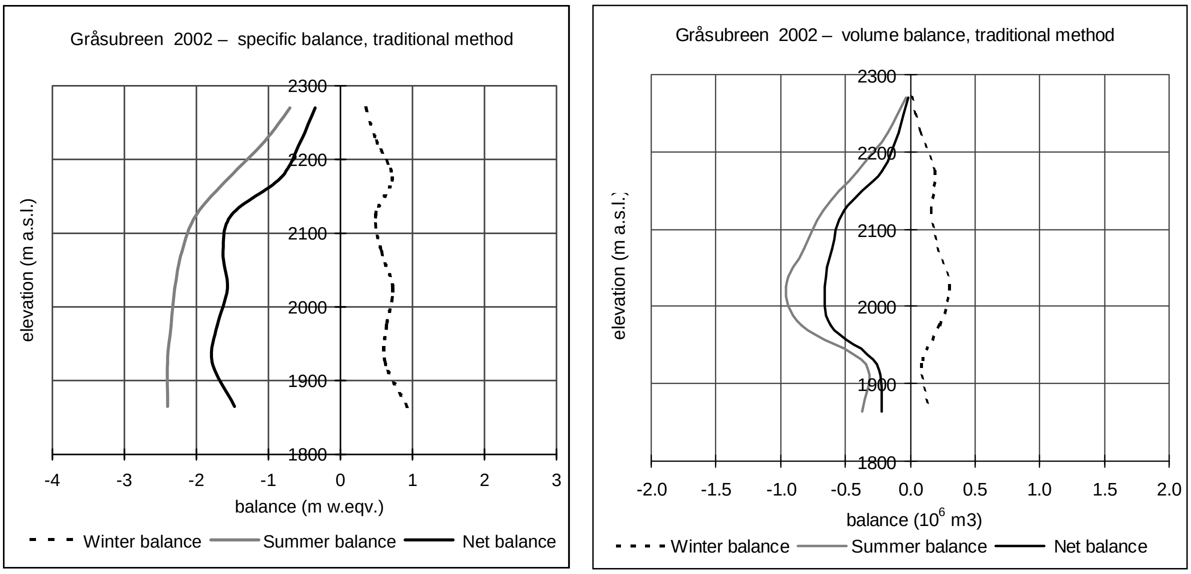


Figure 8-3
Mass balance diagram for Gråsubreen 2002, showing specific balance on the left and volume balance on the right.

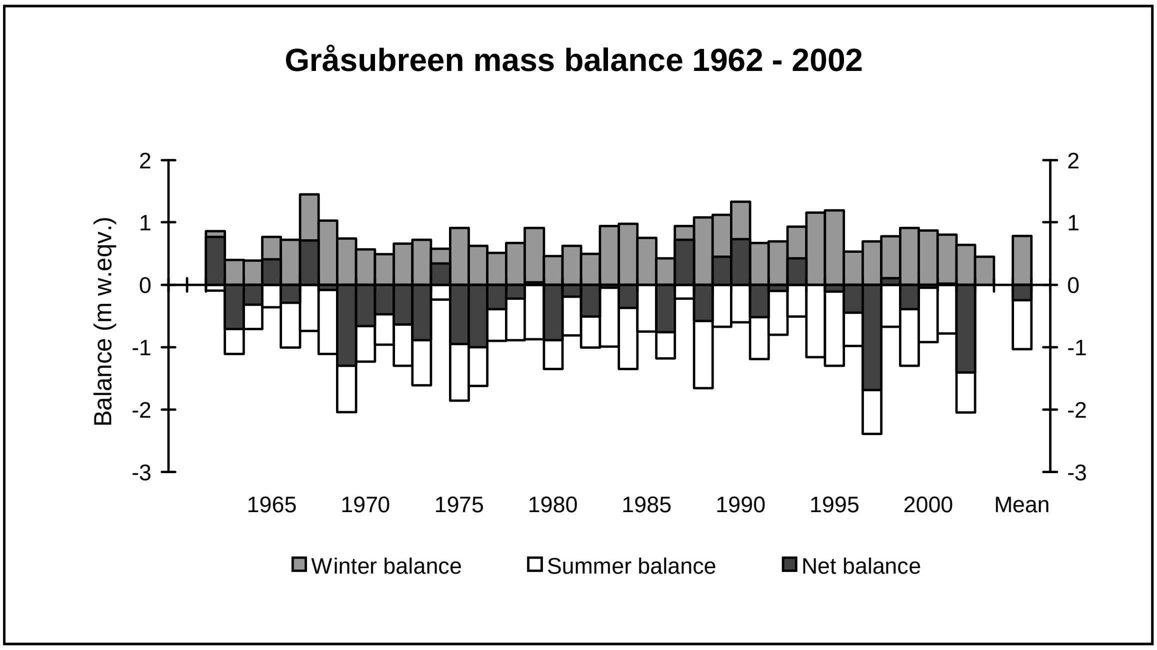


Figure 8-4
Winter, summer and net balance at Gråsubreen during the period 1962-2002. Gråsubreen has had an average annual mass loss of 0.25 m w.eqv. in this period.

9. Svartisheibreen (Hallgeir Elvehøy)

Svartisheibreen is located south-west of the western Svartisen icecap (66°35'N, 13°45'E), covers 5.5 km^2 and drains to the river Glomåga and lake Langvatnet in Rana. The glacier elevation ranges from 1530 m a.s.l. down to the proglacial lake Heiavatnet at 774 m a.s.l., into which the glacier calves. It has been monitored since 1987 in connection with a planned hydropower development. Since 1995 the monitoring programme has been reduced to observations of lake level in Heiavatnet to see if jøkulhlaups occur, and observations of the snow line altitude in order to estimate annual net balance. In 2001 and 2002, Svartisheibreen was used as a test site in the EU-funded project OMEGA (Development of an Operational Monitoring system for European Glacial Areas) in the 5th Frame Programme.

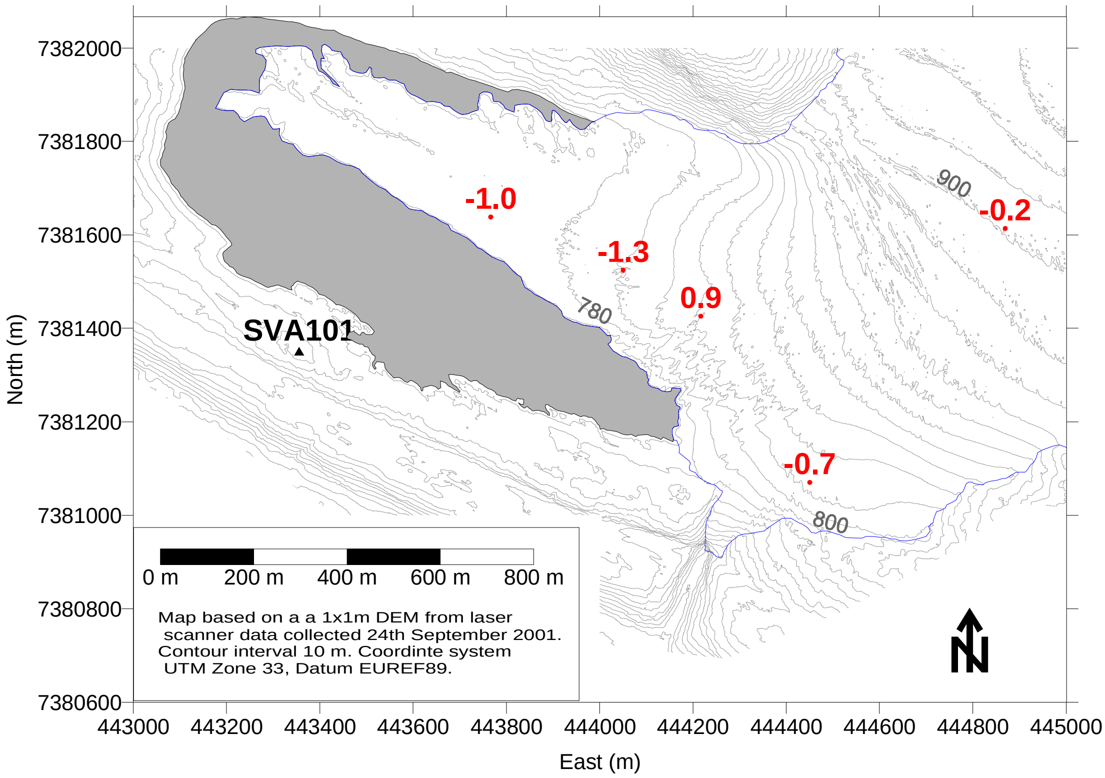


Figure 9-1
Change in surface elevation between 24th September 2001 and 31st July 2002 (metres). The contour lines are generated from a 1m x 1m DEM interpolated from airborne laser scanning data collected on 24th September 2001. The glacier outline (blue line) and the surface of Heiavatnet (grey area) is defined from shaded relief and contour lines based on the same 1m x 1m DEM. The elevation of Heiavatnet in 2001 was 768 m a.s.l., 6 metres below the lake level in 1994.

9.1 Observations 2002

Heiavatnet

Lake Heiavatnet was observed on 31st July 2002. The river from the lake was dry. The lake level was not measured.

Surveying

The glacier was visited on 31st July 2002. Four stakes close to Heiavatnet had melted out. The bottom end of the stakes was positioned, assuming that the stakes were not displaced after they had fallen over. At the fifth stake, 900 m a.s.l., all the winter snow and 1.1 m of glacier ice had melted. The stakes were positioned using differential GPS with SVA101 as a base station. Mean velocity and direction of movement for the period 9th October 2001 – 31st July 2002 was calculated based on these positions.

Equilibrium line altitude

When Svartisheibreen was visited on 31st July the transient snow line altitude (TSLA) was around 1000 m a.s.l., which was about the same as on Engabreen. The TSLA at Svartisheibreen and Engabreen on 23rd August was interpreted from a Landsat-7 ETM+ image as approximately 1100 and 1050 m a.s.l., respectively. On 26th September, the observed TSLA at Engabreen was 1200 m a.s.l., which was the ELA at Engabreen in 2002. The ELA at Svartisheibreen was estimated as 1250 m a.s.l.

9.2 Results

Glacier velocity

The calculated glacier velocities for 24th August – 9th October 2001, 9th October 2001 – 31st July 2002, and 24th August 2001 – 31st July 2002 indicate only small changes in velocity (less than ±1 cm/d) (Kjøllmoen, 2003).

Elevation change

The considered period (24th September – 31st July) is less than a year. The significant surface lowering at three positions indicate that the glacier is shrinking in these areas (Fig. 9-1). The uppermost location probably experienced net surface lowering during 2002, too. Where the measurements indicate thickness increase, the glacier is heavily crevassed. This may have reduced the interpolated surface altitude in this area in the DEM. Hence, the surface elevation change may be exaggerated.

Net balance 2002

The net balance of Svartisheibreen was estimated using two different methods. The first method is based on a relationship between observed net balance at Engabreen (b_n = -0.6 m w.eqv., see Chapter 10) and the net balance at Svartisheibreen (see Fig. 9-2). The resulting net balance at Svartisheibreen was -0.6 m w.eqv. The second method is based on a relationship between the ELA and net balance at Svartisheibreen (see Fig. 9-2). The estimated ELA (1250 m a.s.l.) corresponds to a net balance of -2.4 m w.eqv. Both methods are based on the mass balance measurements carried out on Svartisheibreen in the period 1988-1994. The estimate based on the net balance at

Engabreen is probably more reliable since the ELA at Svartisheibreen in 2002 was outside the range of calculated ELA in 1988-94.

Combining the results gives a specific net balance at Svartisheibreen of -1.5 m w.eqv. The results for the period 1995-2002 are listed in Table 9-1. Cumulative specific balance for the period 1969-2002 is estimated as +9 m w.eqv. (Fig. 9-4).

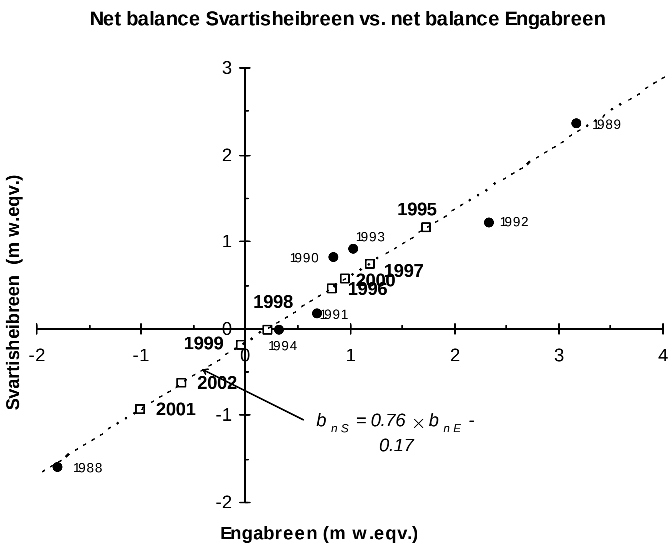


Figure 9-2
Linear regression between net balance of Engabreen and Svartisheibreen (•) based on simultaneous observations during the period 1988-94. Net balance of Svartisheibreen for the period 1995-2002 (□) is modelled using regression equations.

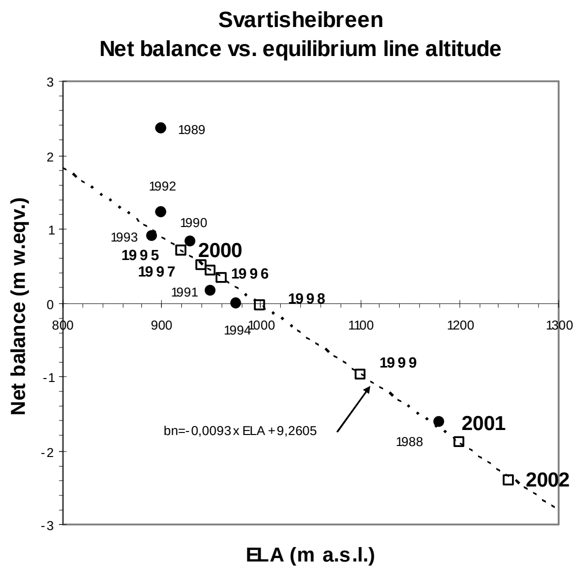


Figure 9-3
Linear regression between the elevation line altitude (ELA) and net balance (b_n) on Svartisheibreen based on measurements for the period 1988-94 (•). The results from 1989 were discarded in the regression analysis. Net balance for the period 1995-2002 (□) is modelled using a regression equation. Notice that the ELA in 2002 was outside the range of calculated ELA in 1988-94.

Year	Date of visit	ELA (m a.s.l.)	Heiavatnet filled ?	Net balance method 1[1]	method 2[2]	Mean
1995	20th Sep	920	Yes	1.2	0.7	0.9
1996	19th Sep	960	Yes	0.5	0.3	0.4
1997	4th Oct	940[3]	Yes	0.7	0.6	0.7
1998	1st Oct	1000	Yes	0.0	0.0	0.0
1999	22nd Sep	1100	No	-0.2	-1.0	-0.6
2000	21st Sep	950	No	1.0	0.4	0.7
2001	24th Sep	1200[4]	No	-0.9	-1.9	-1.4
2002	31st July	1250[5]	No	-0.6	-2.4	-1.5

[1]*Based on relation between net balance of Engabreen and Svartisheibreen.*

[2]*Based on relation between ELA and net balance at Svartisheibreen.*

[3]*Estimated from summer observations.*

[4]*Estimated from aerial photographs from 25th August and further melting until 25th September.*

[5] *Estimated from Landsat-7 ETM+ scene 23rd August and comparison with Engabreen.*

Table 9-1
Estimates of the equilibrium line altitude (ELA) at Svartisheibreen, the water level in Heiavatn, and modelled net balance of Svartisheibreen for the period 1995 - 2002.

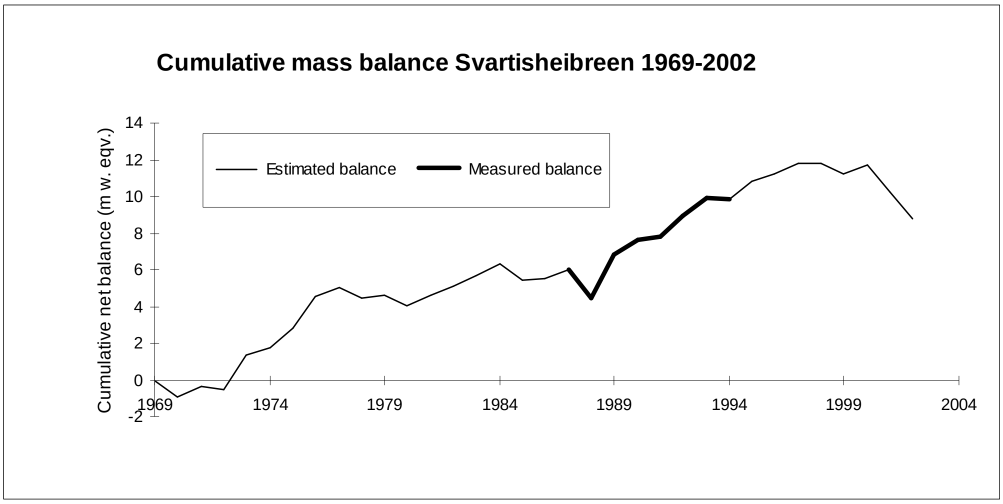


Figure 9-4
Cumulative specific net balance of Svartisheibreen for the period 1969-2002. Estimated net balance (thin solid line) is modelled from net balance on Engabreen (1969-87), and from the ELA on Svartisheibreen and net balance of Engabreen (1995-2002).

10. Engabreen (Hallgeir Elvehøy)

Engabreen (66°40'N, 13°45'E) is a 38 km^2 north-western outlet from the western Svartisen ice cap. It covers an altitude range from 1594 m a.s.l. (at Snøtind) down to 7 m a.s.l. (at Engabrevatnet), as shown in Figure 10-1. Mass balance measurements have been performed annually since 1970.

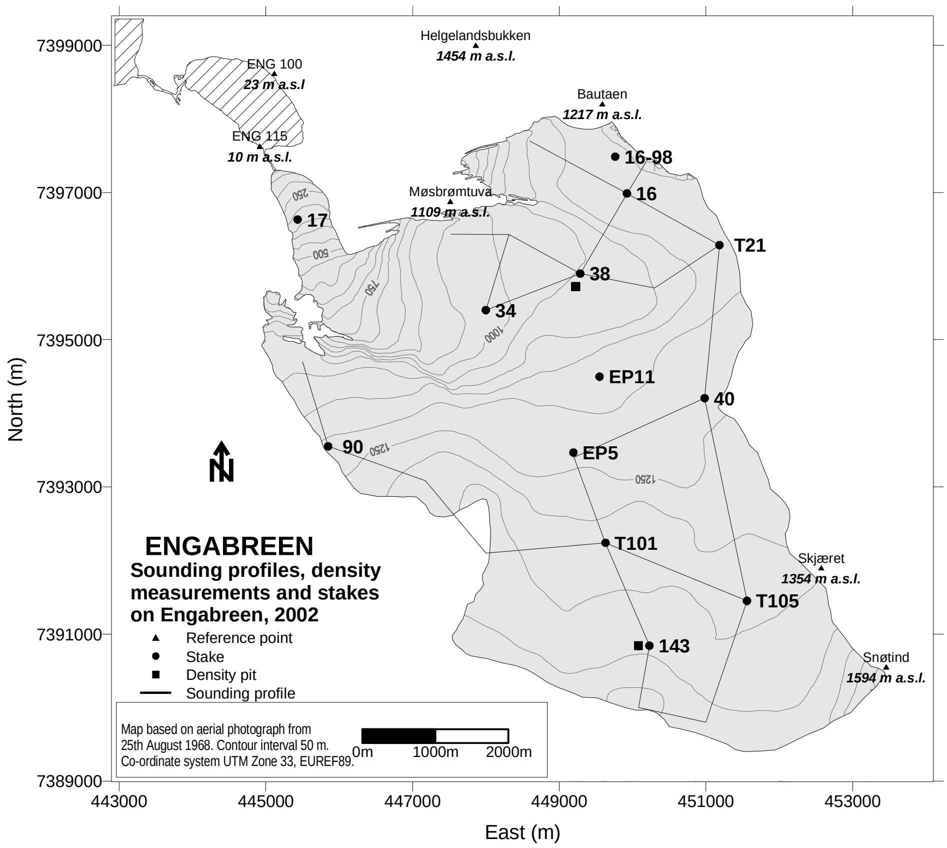


Figure 10-1
Location of stakes, density pit and sounding profiles at Engabreen in 2002.

10.1 Mass balance 2002

Fieldwork

Snow accumulation measurements were carried out between 24th and 28th May. The locations of stakes and towers, density pit, core samples and sounding profiles are shown in Figure 10-1. The calculation of winter balance is based on:

- Direct measurements of snow depth at stake 17 and towers T21, T101 and T105, giving 0.0, 5.3, 6.8 and 7.0 m of snow, respectively. At stake 17, 2.7 m of ice had melted since 26th September 2001.

- Core samples collected between 24th and 28th May at stake 34, stake 38, stake 16-02, stake 90, stake 40 and stake 143. The samples gave 3.6, 5.0, 5.8, 5.6, 5.9 and 7.2 m of snow, respectively.

- Snow density measured to a depth of 5 m at stake 38, and to 7.2 m depth at stake 143. Mean snow density was 0.56 g/cm^3 and 0.52 g/cm^3, respectively.
- 152 snow depth soundings along 33 km of profiles. The snow depth was between 5.5 and 7.5 m above 1200 m a.s.l., and between 4 and 6 m between 950 and 1200 m a.s.l.

The net balance measurements were carried out on 26th September. There was up to 0.6 m of new snow on the glacier. From stake measurements the transient snow line altitude (TSL) was about 1200 m a.s.l.

The net balance was observed at 12 positions between 300 and 1400 m a.s.l. At the glacier tongue (300 m a.s.l.), 14 m of ice had melted during the summer. At 960 m a.s.l. all the winter snow and 3.5 m of ice had melted. At 1050 m a.s.l. all the winter snow and 1.5 m of firn had melted away. Around 1200 m a.s.l. 5 - 6 m snow and some firn at certain stakes had melted away. Above 1200 m a.s.l. approximately 5 m of snow had melted away, and up to 2.2 m of snow remained at the stakes.

Results

The mass balance is calculated using the stratigraphic method, which reports the balance between two successive "summer surfaces", excluding snow accumulation before the date of net balance measurements but also excluding ablation after net balance measurements. The late autumn melting is normally restricted to the lower parts of the glacier. It is insignificant compared to winter accumulation and summer ablation, and it is usually difficult to determine accurately. The extent of late autumn melting could not be defined.

The calculations were performed using a map from 1968 and drainage divides calculated from bottom topography and ice thickness (Kennett & Elvehøy, 1995).

Winter balance

The calculations of winter balance were based on point measurements of snow depth (towers, probing and core drillings) and on snow density measurements (Fig. 10-1). Water equivalent profiles were modelled from the snow density measured at stake 38 and 143. Using these models, the mean snow density for 5 m of snow was calculated as 0.53 g/cm^{3}at stake 38 and 0.51 g/cm^{3}at stake 143. The models based on the density profiles at stake 38 and 143 were then used to calculate the water equivalent value of the snow depth measurements below and above 1225 m a.s.l., respectively.

Point values of the snow water equivalent (SWE) were plotted against altitude in a diagram, and a curve was drawn based on visual evaluation. No snow depth observations were carried out below 950 m a.s.l. Below 950 m a.s.l. the winter balance curve was interpolated based on the observed snow depth around stake 34 and the observed negative winter balance at stake 17 (300 m a.s.l.). Based on this altitudinal distribution curve, the winter balance was calculated as 2.9 ±0.2 m w.eqv., which corresponds to a volume of 110 ±8 million m^3 of water. This is 98 % of the mean value for the period from 1970-2001 (2.95 m w.eqv.), and 108 % of the mean value for the 5-year period 1997-2001.

Summer balance

The summer balance was measured and calculated directly at nine locations between 300 and 1400 m a.s.l. Based on the measurements an altitudinal distribution curve was drawn (Fig. 10-2). The summer balance was calculated as -3.5 ±0.2 m w.eqv., which equals a volume of -132 ±8 million m^3 water (Tab. 10-1). This is 155 % of the average for the period 1970-2001 (-2.24 m w.eqv.), and 145% of the average for the 5-year period 1997-2001.

Net balance

The net balance of Engabreen for 2002 was calculated as –0.6 ±0.3 m w.eqv., which corresponds to a volume loss of 20 ±10 mill. m^3 water. The mean value for the period 1970-2001 is +0.71 m w.eqv., and +0.27 m w.eqv for 1997-2001. The equilibrium line altitude (ELA) was determined as 1200 m a.s.l. from the net balance curve in Figure 10-2. This gives an accumulation area ratio (AAR) of 54 %. The mass balance results are shown in Figure 10-2 and Table 10-1. The results from 2002 are compared to mass balance results for the period 1970 - 2001 in Figure 10-3.

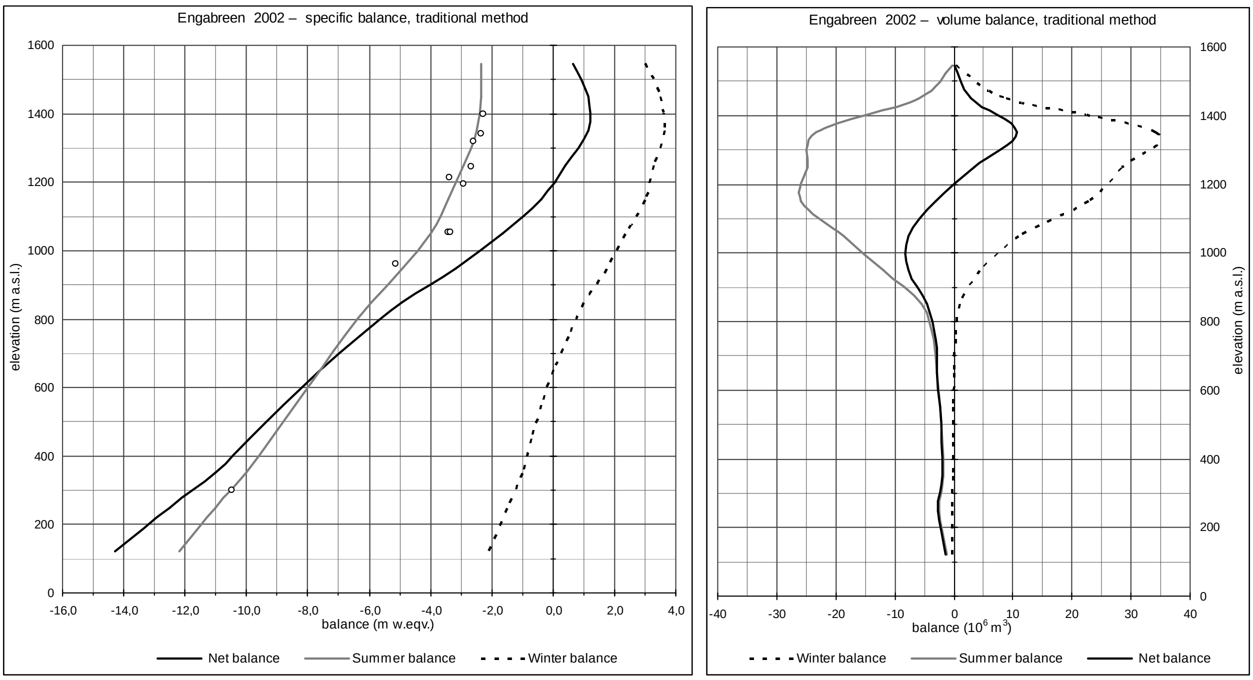


Figure 10-2
Mass balance diagram showing specific balance (left) and volume balance (right) for Engabreen in 2002. Summer balance at stakes and towers is shown as circles (○).

Mass balance Engabreen 2001/02 – traditional method

Altitude (m a.s.l.)	Area (km^2)	Winter balance, Measured 26th May 2002: Specific (m w.eqv.)	Winter balance: Volume (10^6 m^3)	Summer balance, Measured 26th Sep 2002: Specific (m w.eqv.)	Summer balance: Volume (10^6 m^3)	Net balance, Summer surface 2001 - 2002: Specific (m w.eqv.)	Net balance: Volume (10^6 m^3)
1500 - 1594	0,12	3,00	0,4	-2,35	-0,3	0,65	0,1
1400 - 1500	2,51	3,50	8,8	-2,35	-5,9	1,15	2,9
1300 - 1400	9,35	3,65	34,1	-2,50	-23,4	1,15	10,8
1200 - 1300	8,55	3,30	28,2	-2,90	-24,8	0,40	3,4
1100 - 1200	7,60	3,00	22,8	-3,40	-25,8	-0,40	-3,0
1000 - 1100	4,66	2,35	11,0	-4,00	-18,6	-1,65	-7,7
900 - 1000	2,46	1,75	4,3	-4,90	-12,1	-3,15	-7,7
800 - 900	0,94	1,00	0,9	-5,90	-5,5	-4,90	-4,6
700 - 800	0,50	0,50	0,3	-6,80	-3,4	-6,30	-3,2
600 - 700	0,37	0,00	0,0	-7,60	-2,8	-7,60	-2,8
500 - 600	0,27	-0,40	-0,1	-8,40	-2,3	-8,80	-2,4
400 - 500	0,21	-0,70	-0,1	-9,20	-1,9	-9,90	-2,1
300 - 400	0,17	-1,00	-0,2	-10,00	-1,7	-11,00	-1,9
200 - 300	0,22	-1,50	-0,3	-11,00	-2,4	-12,50	-2,8
40 - 200	0,10	-2,10	-0,2	-12,20	-1,2	-14,30	-1,4
40 - 1594	38,0	2,89	109,8	-3,48	-132,2	-0,59	-22,4

Table 10-1
Specific and volume winter, summer, and net balance calculated for 100 m elevation intervals at Engabreen in 2002.

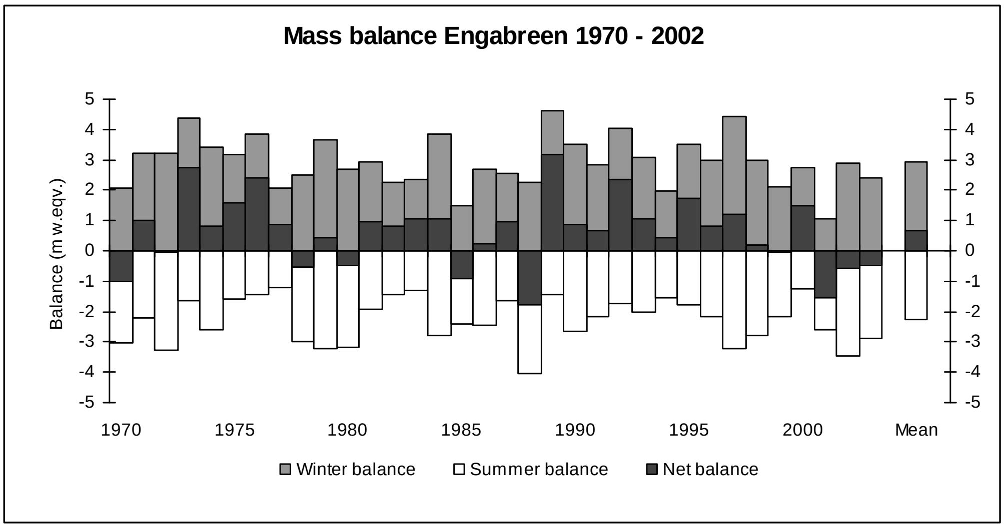


Figure 10-3
Mass balance at Engabreen during the period 1970-2002. The accumulated surplus amounts to 22 m water equivalent.

10.2 Front position change

Changes in front position are observed from fixed points aligned with the central flow direction of the glacier. On 26th September 2002 the glacier terminus had melted back 6 m compared with 26th September 2001. The terminus was close to its position in 1984 before the 1985-91 retreat (Fig 10-4).

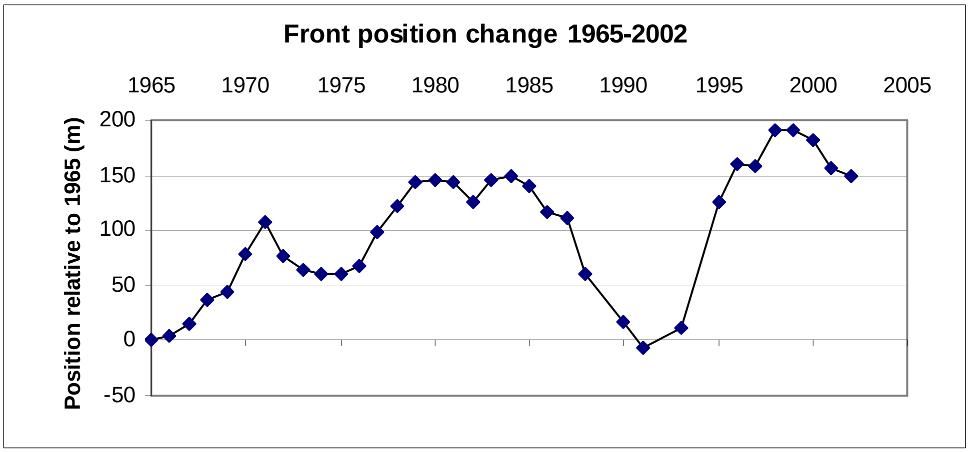


Figure 10-4
Front position change between 1965 and 2002 measured as change in position along a line parallel to a central flow line. The location of the line (the fixed points) was shifted in 1996 due to an assessment of avalanche risk at the original line. The two lines had been measured simultaneously for some time.

10.3 Meteorological measurements

A meteorological station recording air temperature, global radiation, precipitation, wind speed and wind direction is located on the nunatak Skjæret (1 364 m a.s.l.) close to the drainage divide between Engabreen and Storglombreen (Fig. 10-1). The station has been recording data since 1995 with some data gaps. The nearest meteorological station is in Glomfjord (39 m a.s.l.) 19 km north of Skjæret. This station has been operated by the Norwegian Meteorological Institute (DNMI) since 1916.

The temperature record from Glomfjord shows that close to sea level there can be repeated periods of melting throughout the winter (Fig. 10-5). On the upper part of the glacier the melting season started late in May and ended around 15th September. The mean temperature gradient in 2002 between Glomfjord and Skjæret was -0.73 °C/100m. During the melting season (20thMay – 15th September) the average temperature gradient was the same (-0.73 °C/100m).

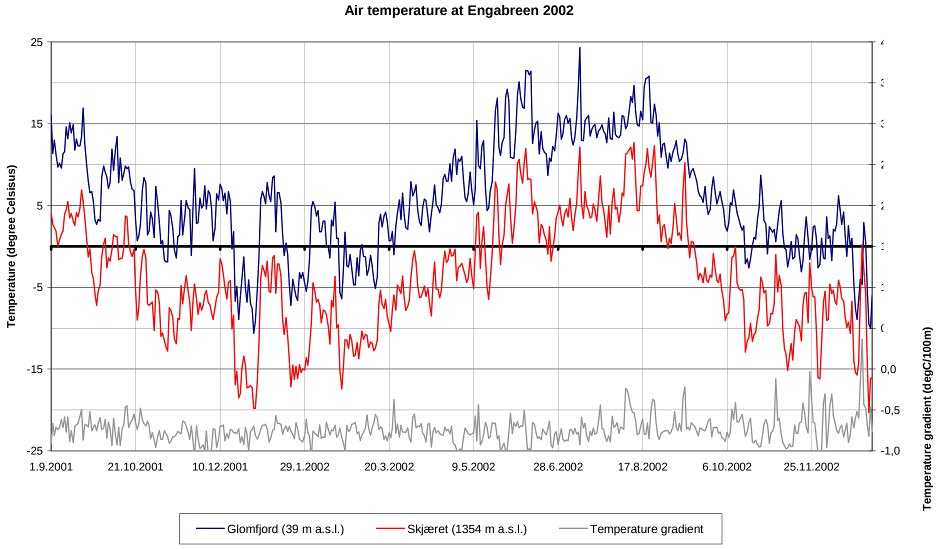


Figure 10-5
Daily mean air temperature at Skjæret (159.20.20) and Glomfjord (80700) between 1st September 2001 and 31st December 2002, and daily temperature gradient between Glomfjord and Skjæret.

10.4 Svartisen subglacial laboratory

Svartisen Subglacial Laboratory is a unique facility situated under Engabreen. It allows direct access to the bed of the glacier for the purposes of measuring sub-glacial parameters and performing experiments on the ice. Further general information about the laboratory is available in report number 14 in NVE's document series for 2000, entitled 'Svartisen Subglacial Laboratory' (Jackson, 2000).

Pressure measurements

Six load cells were installed at the bed of the glacier in December 1992 in order to measure variations in subglacial pressure. Four of these were still operating in 2002. A further two load cells were installed in November 1997 and were also still operating in 2002 (Figure 10-6). The load cells are Geonor P-105 Earth Pressure Cells. Readings are recorded from the load cells at 15 minute intervals (more frequently when experiments are being performed). During 2002, the load cells were operational between 1st January and 24th August (with a 32-hour break at the end of February). On 24th August a problem occurred, which led to data no longer being saved. The problem could not be fixed before the spring of 2003.

Pressure sensor records for 1st January to 17th March 2002, are shown in Figure 10-7. An unusual event was recorded in early January. Generally, the first few months of the year show little subglacial activity. However, there were several days of heavy precipitation between 3rd and 16th January with over 130 mm rain recorded in Glomfjord on 11th January alone. Temperatures during this period were much warmer than usual, and were close to 0° several times even as high as Skjæret (Figure 10-5), so that much of this precipitation fell as rain on the glacier, rather than snow.

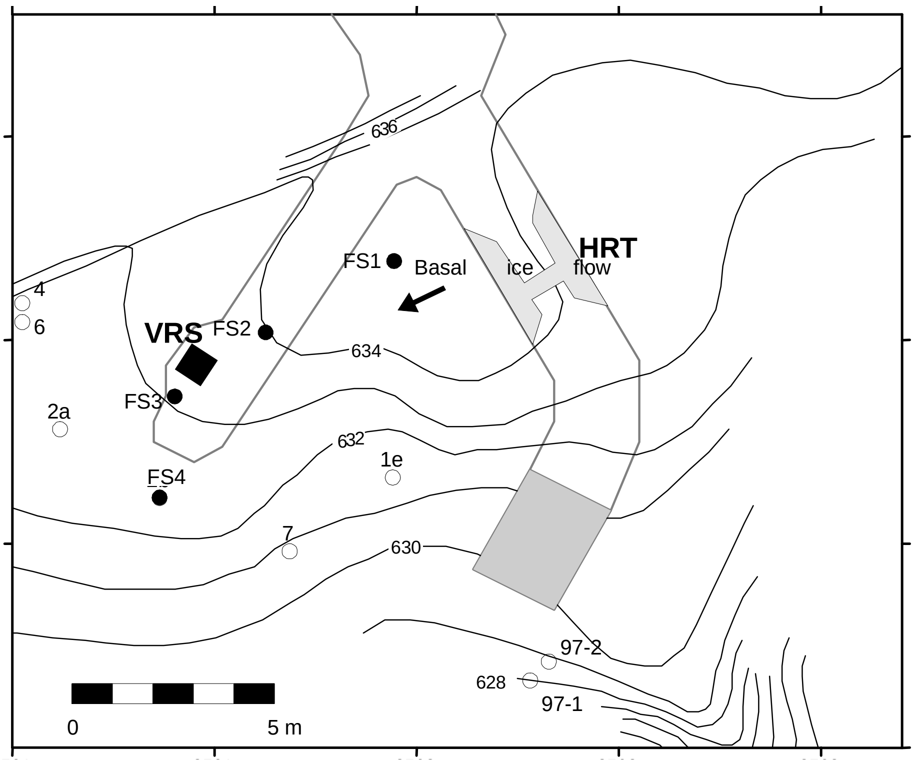


Figure 10-6
Tunnel system showing locations horizontal research tunnel (HRT) and vertical research shaft(VRS), load cells 1e, 2a, 4, 6, 7 (no longer working), 97-1 and 97-2 and boreholes, marked FS.

As a result of this, subglacial discharge as measured in the subglacial tunnel was about 100 times the normal amount for January, reaching over 12 cubic metres per second, a value more typical of mid-June. Several pressure drops are seen in the load cell record, reflecting the rapid input of water to the system.

The behaviour of the pressure records for the load cells 97-1 and 97-2 in late January is interesting. These two load cells are very near each other, with LC 97-1 on the lee side of a small bump and LC 97-2 a little upstream of it. On about 14th January the load cells both show a fairly rapid decrease in pressure. 97-1 continues to drop, reaching a minimum on about 22nd January. 97-1 shows a steep increase starting on 28th January, at the same time as 97-2 shows a sharp decrease, before it reaches its minimum. Both load cells show increases to higher pressure than normal before returning to fairly stable levels. This event was probably caused by a migrating channel. This caused pressures of approximately zero as it passed over, and also caused highs in pressure before and after, as the pressure is locally high at the walls of a channel due to the bridging effect.

Data for the period from 18th March to 19th April are not shown, as there was experimental work in progress for several weeks during this period leading to very noisy data, and the experimental results will be reported elsewhere.

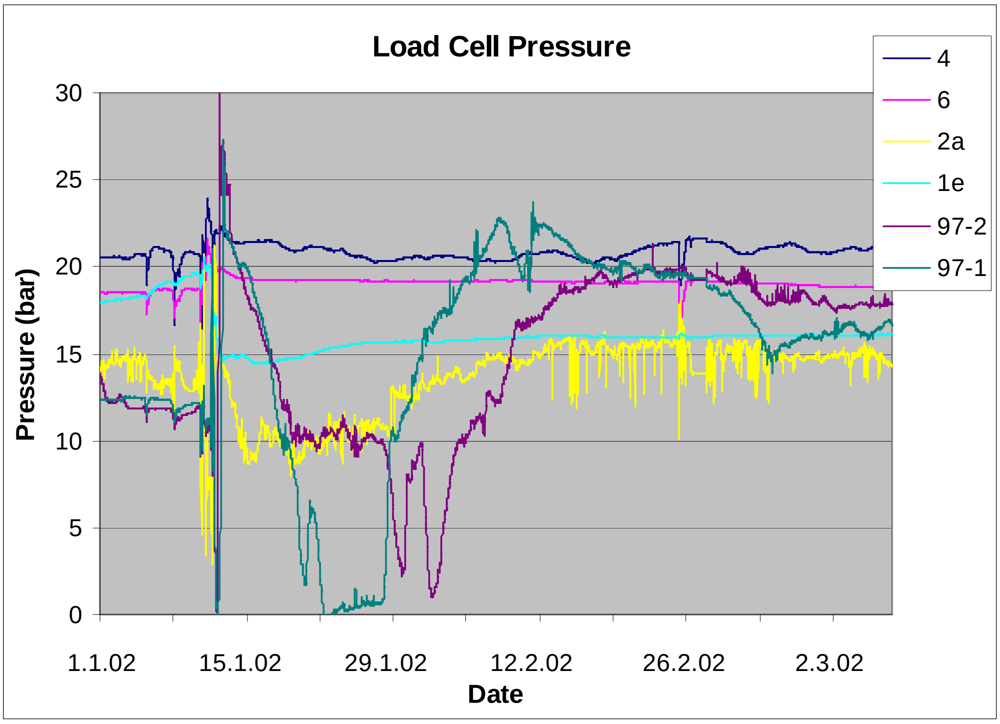


Figure 10-7
Data logger records for the period January to March.

Pressure sensor records for the spring – early summer period from 20th April to 4th July, are shown in Figure 10-8. The event on about 23rd April is probably related to heavy rainfall on 22nd April, which was translated into a rapid increase in subglacial discharge. Measurements of discharge out of the sediment chamber rose from 0.1 cubic metres per second at midday on 22nd to ten times this amount by midnight of 23rd, and rose further to 5 cubic metres per second over the next few days. The response of the load cells to this sudden water input is rapid, with the pressure showing the initial sudden drop in the early hours of 23rd.

Most of the pressure records are relatively quiet after this, before recording a major signal about 11th May, related to the increase in discharge on 10th May that marks the beginning of the summer subglacial hydrology conditions and a well-defined drainage system. Shortly after this, load cells 97-1 and 97-2 show a similar event to that seen in January, possibly showing again the passage of a migrating channel. There appears to be another event about 10 days later, but in this case 97-2 reaches a very high pressure, 34 bars, while 97-1 returns to approximately normal levels. This event is hard to explain in terms of a migrating channel.

The pressure records for June show no large events, and are typical for summer months. There is a diurnal signal to most of the load cells records, although it is somewhat noisy. There are a couple of small events where the signals for 97-1 and 97-2 are anti-correlated. This has previously been explained by Lappegard (1999) as being due to filling in of the horizontal research tunnel a couple of months after it had been melted out. The timing with research work in the tunnel in April corresponds

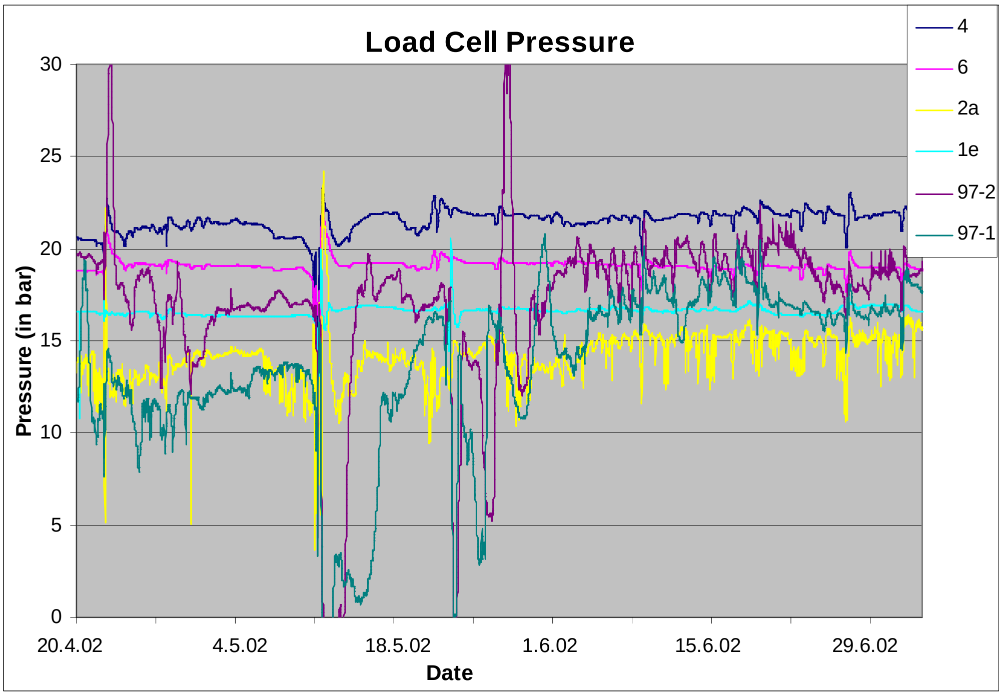


Figure 10-8
Data logger records for the period April to July.

well, but the physical explanation is not obvious, and this feature isn't always observed after tunnels have been melted out.

Pressure sensor records for the rest of the summer period, from 7th July to 24th August, are shown in Figure 10-9. The records show a clear diurnal signal, especially for load cells 97-1, 97-2 and 4, but otherwise are fairly quiet. The discharge in the subglacial sediment chamber has a couple of distinct peaks in July, the first on 12th July probably related to very warm weather, with temperatures approaching 15°C at Skjæret, and the second on 29th July probably related to precipitation between 26th and 29th. The discharge measured more than tripled for both events but the first event is not seen at all at the load cells, and the second event was reflected on some sensors (especially 4, 6 and 97-2) but is not very dramatic. Note the clear diurnal signal between 4th and 12th August, especially at load cells 4 and 6, which almost disappears over the following days. The temperature measured at Skjæret was very warm, almost 15°C on several occasions, up to 13th August, then suddenly dropped to under 3°C, which is too cold to cause a clear diurnal signal. A sudden increase in subglacial discharge to more than 80 cubic metres per second on 15th August, unrelated to precipitation, is reflected in the load cell records.

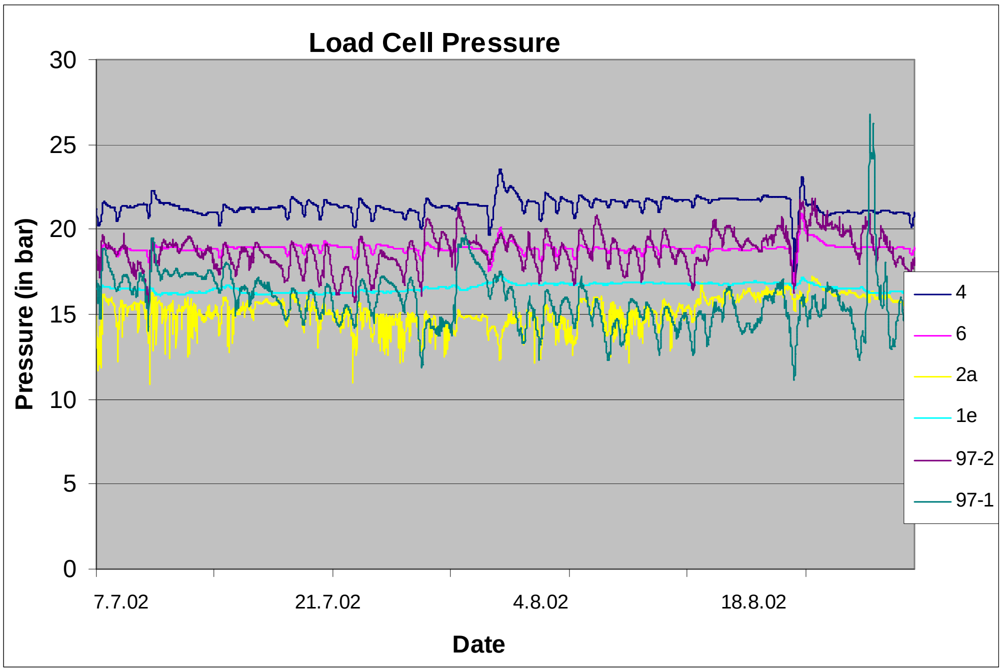


Figure 10-9
Data logger records for the period July to August.

Research projects

Two major research projects took place in the subglacial laboratory in 2002. The first was a continuation of the doctoral work of University of Oslo student, Gaute Lappegard. He performed several high-pressure pump experiments in the laboratory in mid-March and in early July.

The second project involved a group of American researchers led by Neal Iverson of Iowa State University and Denis Cohen of Yale University, in collaboration with Urs Fischer of ETH in Zurich. They performed two experiments. The first consisted of installing a smooth granite tablet flush with the bedrock surface so that the debris-charged basal ice slid across it. The shear traction on the tablet, total normal stress, water pressure at the tablet surface, and upward heat flux were recorded. This was a repeat of work done last year that had been terminated early due to instrument failure.

The second experiment involved installing an instrumented till prism under the glacier, using a trough that had been excavated the previous year. Water was pumped to the till to bring its pore-water pressure close to the total normal stress. Instruments in the till recorded shear deformation, total stress normal to the till surface, pore-water pressure and dilation and contraction at several places in the till. Unlike the previous year, the instruments were left in place, rather than being excavated after several days of measurements.

11. Storglombreen (Hallgeir Elvehøy)

Storglombreen (66°41'N, 14°00'E) is the largest outlet from the Svartisen icecap. It covers an area of 62.4 km^2 and drains the western Svartisen ice cap to Lake Storglomvatnet (Fig. 11-1). Most of its area is located between 900 and 1300 m a.s.l. Three outlet glaciers calve into the lake. Mass balance measurements were carried out during the four years from 1985 to 1988, and re-commenced in 2000.

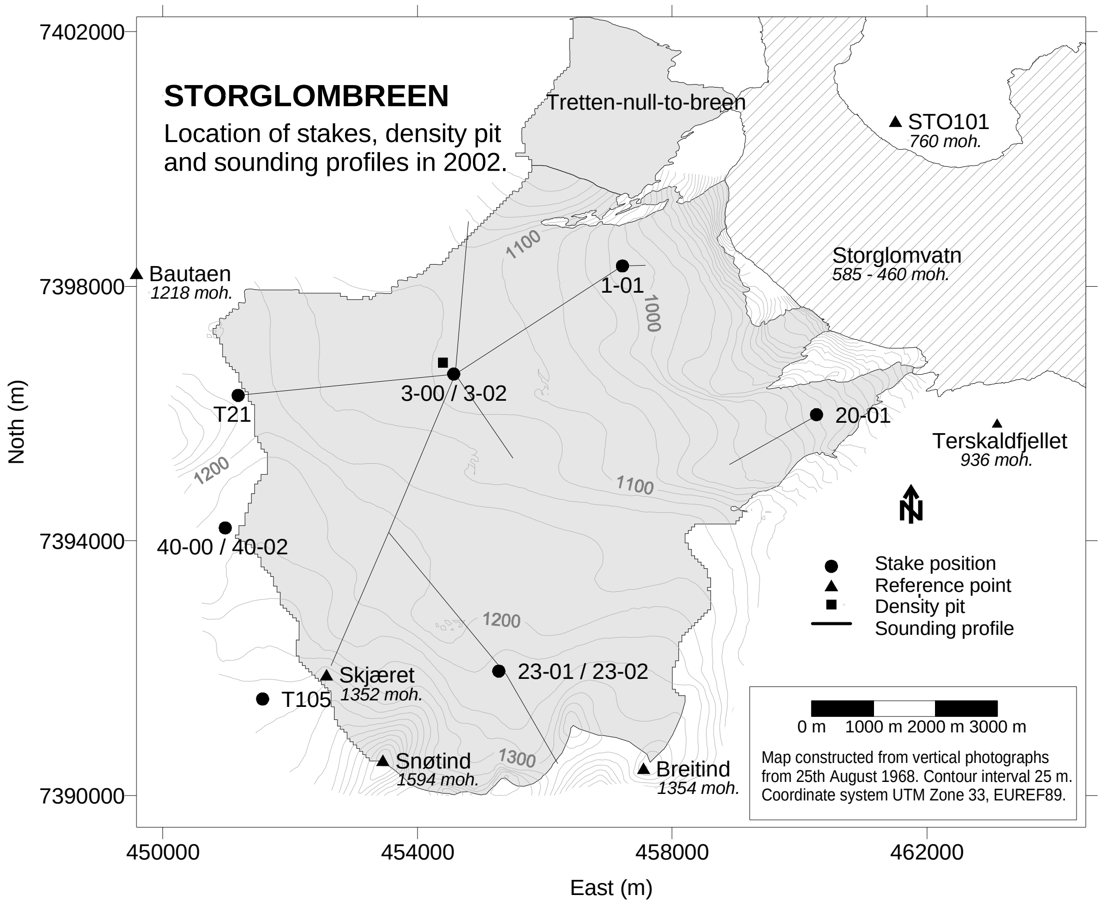


Figure 11-1
Location of stakes, density pit and sounding profiles at Storglombreen in 2002. To calculate the summer balance, three stakes on Engabreen positioned close to Storglombreen were also used.

11.1 Simplified observation network

Based on the extensive monitoring program from 1985-88, a simplified observation network for mass balance measurements has been established. Figure 11-2 shows a linear regression between mean water equivalent for all snow depths along the 1985-88 profiles (corresponding to the 2002 profiles in Fig.11-1), and specific winter balance for the entire glacier. A linear regression was performed between summer balance at stake 3 and specific summer balance (without calving) for the entire glacier. The calculations were performed using a map from 1968 and drainage divides calculated from bottom topography and ice thickness (Kennett & Elvehøy, 1995).

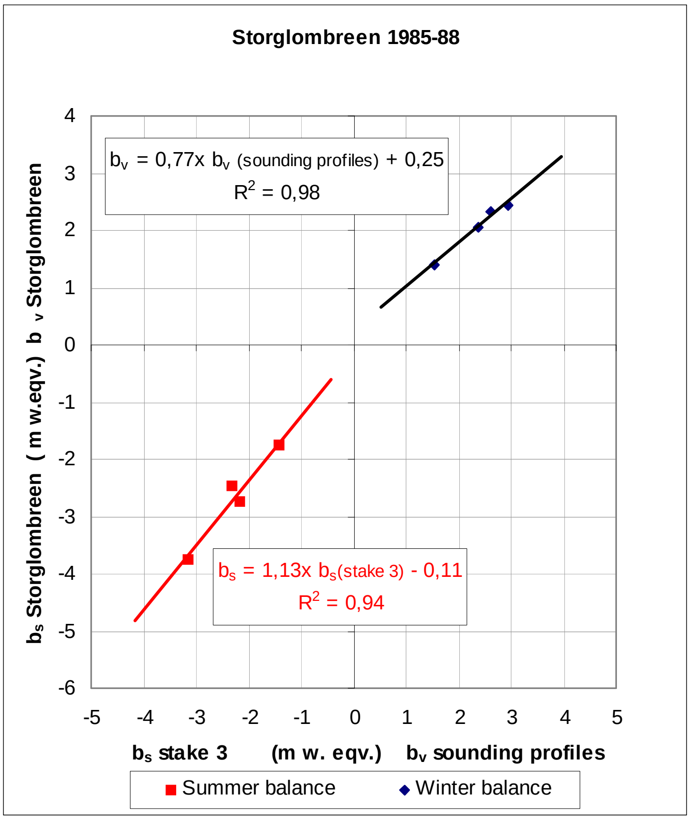


Figure 11-2
In black: regression between winter balance calculated from balance maps (Y-axis) and selected snow depth profiles (X-axis).
In red: regression between summer balance calculated from balance maps (Y-axis) and summer balance at stake 3 (X-axis). The summer balance values are without calving.

11.2 Mass balance 2002

Fieldwork

Winter accumulation measurements were carried out between 24th and 28th May. The location of stakes, density pit, core samples and sounding profiles are shown in Figure 12-1. The calculation of the winter balance was based on:

- Sounded snow depth, which at stake 20-01 and stake 1-01 was 0.75 and 3.15 m, respectively. Comparison to stake readings showed that 0.15 and 0.10 m of ice had melted at these locations after stake measurements 26th September 2001. At stake T21 the snow depth was 5.95 m.
- Snow depth at location 3 and 23 determined by coring as 4,75 and 5.4 m.
- Snow density measured to a depth of 4.75 m at stake 3-02. Mean snow density was 0.52 g/cm^3.
- 114 snow depth soundings along approximately 22 km of profiles in the area located between 910 and 1345 m a.s.l. Most observations showed between 4 and 6 m of snow, and the summer surface was generally well defined.

Summer ablation measurements were carried out on 26th September. At that time up to 0,4 m new snow had fallen on the glacier. All the winter snow had melted away on

Storglombreen. At Engabreen some winter snow remained at stakes 40 and T105. Some winter snow may have remained in small areas on the north slopes of Snøtinden.

During the summer, 0.75 m snow and 5.15 m ice melted at stake 20. At stake 1, 3.15 m of snow and 3.00 m of ice had melted away. At the plateau, 4 - 6 m of snow and 0.5 m firn had melted.

Results

The calculations were performed based on a map from 1968 and drainage divides calculated from bottom topography and ice thickness (Kennett & Elvehøy, 1995). The mass balance was also calculated using the regression equations established from the observation period 1985-1988 (Fig. 11-2).

Winter balance

The winter balance for 2002 was calculated as the sum of late autumn ablation calculated from comparison of stake measurements and soundings in May 2002, and snow accumulation calculated from snow depth and snow density measurements in May 2002.

The altitudinal distribution of the autumn melting was estimated based on the observations of ablation after 26th September 2001 at stake 20 and stake 1 at Storglombreen. No melting was estimated for areas above 1100 m a.s.l. The density of the glacier ice was set as 0.9 g/cm^3. The total volume of ablation was calculated as 2 million m^3 of water or 0.03 m w.eqv. distributed over the glacier area.

The winter accumulation was calculated from point measurements of snow depth (stakes and soundings) and measurements of snow density at stake 3 (Fig. 11-1). The snow density measurements were used to model a water equivalent profile. According to this model, the mean snow density for the upper 5 m of snow was 0.52 g/cm^3. This model was used to convert all snow depth observations to water equivalent values.

The total winter accumulation was calculated from the altitudinal distribution of the snow accumulation. Point values of the snow water equivalent were plotted against altitude, and a representative curve was drawn based on the mean value in each 100 m elevation interval. As snow depth was observed only between 900 and 1300 m a.s.l., the mean balance curve for the period 1985-1988 was used as a basis for the curve below 900 m a.s.l. and above 1300 m a.s.l. Using this method the winter accumulation was calculated as 2.4 ±0.2 m w.eqv., which corresponds to a volume of 150 ±10 million m^3 of water.

The winter accumulation was also calculated using the regression equation defined in Figure 11-2. The mean water equivalent for 94 snow depth measurements along the profiles shown in Figure 11-1 was 2.7 m. This corresponds to a specific winter accumulation of 2,3 m, which is close to the result above.

The winter balance in each altitude interval was calculated as the sum of autumn ablation and snow accumulation. The specific winter balance was 2.4 ±0.2 m w.eqv. or 150 ±10 million m^3 water. The altitudinal winter balance distribution is shown in Figure 11-3 and Table 11-1. The mean winter balance for 1985-88 and 2000-01 is 2.01 m w.eqv.

Summer balance

The summer balance was measured and calculated directly at four locations on Storglombreen (20, 1, 3 and 23) and two positions on Engabreen (40 and T105) located very close to the ice divide (Fig. 11-1). The summer balance curve was drawn based on these six point values, with the aid of the mean balance curve for the period 1985-1988.

The contribution from calving and ice avalanches was estimated, as it was for the period 1985-1988. This contribution is estimated as -7 million m^3 water, based on an timated terminus length of 1.6 km, a mean terminus height of 50 m and a glacier velocity of 100 m/a. The total summer balance, including the calving contribution, totalled –220 ±20 million m^3 water, which is equal to a specific balance of –3.6 ±0.3 m w.eqv. The mean summer balance for the six previously measured mass balance years (1985-1988 and 2000-2001) is –2.6 m w.eqv. The calculated summer balance is 137 % of the 6-year average.

The summer balance was also calculated with the regression equation shown in Figure 11-2. The summer balance at stake 3 was –2.8 m w.eqv., which corresponds to a specific summer balance excluding calving for Storglombreen of –3.3 m w.eqv., and –3.4 m w.eqv. when calving was included, which is close to the result above.

Net balance

The net balance of Storglombreen for 2002 was –1.3 ±0.4 m w.eqv., which corresponds to a mass loss of 80 ±30 million m^3 water. The mean value for 1985-1988 and 2000-01 was -0.61 m w.eqv. Since practically all of the winter snow melted during the summer, the equilibrium line altitude (ELA) was undefined, and the accumulation area ratio (AAR) is 0%.

The mass balance results are shown in Table 11-1 and Figure 11-3. The results from 2002 are compared with mass balance results for the period 1985-1988 and 2000-01 in Figure 11-4.

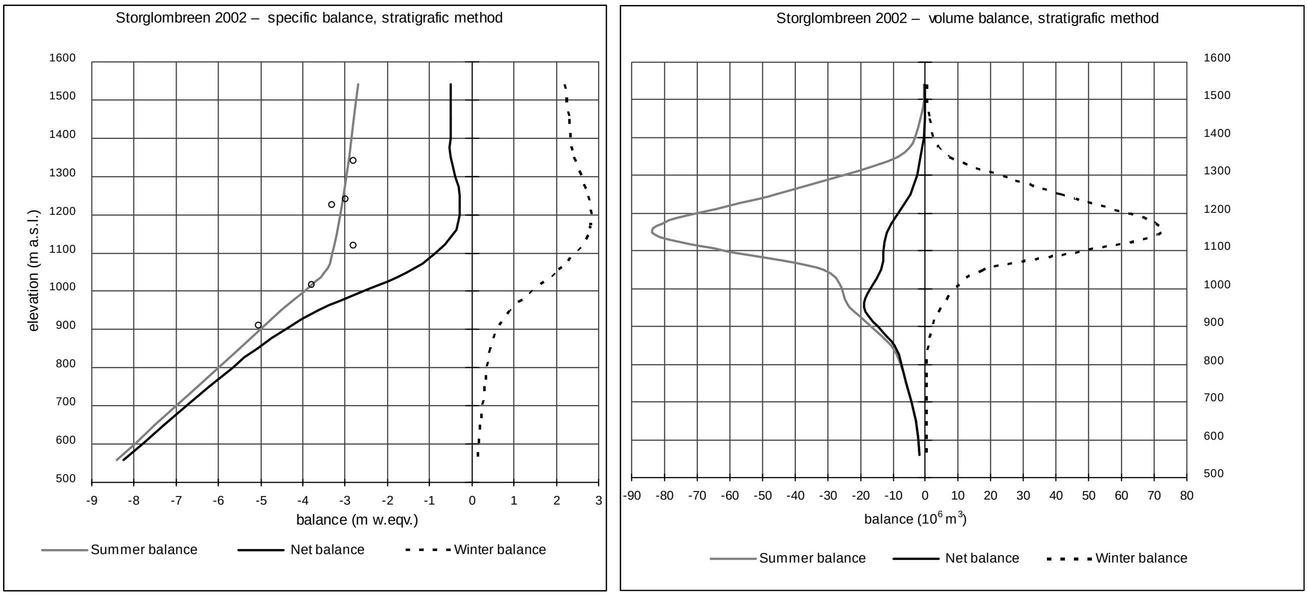


Figure 11-3
Winter-, summer and net balance for Storglombreen in 2002, showing specific balance (left) and volume balance (right). Summer balance at stakes is shown as circles (°).

Winter balance Storglombreen 2001/02 – stratigrafic method

Altitude (m a.s.l.)	Area (km^2)	Winter balance Measured 26th May 2002		Summer balance Measured 26th Sep 2002		Net balance Summer surface 2001 - 2002	
		Specific (m w.eqv.)	Volume (10^6 m^3)	Specific (m w.eqv.)	Volume (10^6 m^3)	Specific (m w.eqv.)	Volume (10^6 m^3)
1500 - 1580	0,18	2,20	0,39	-2,70	-0,48	-0,50	-0,09
1400 - 1500	0,58	2,30	1,32	-2,80	-1,61	-0,50	-0,29
1300 - 1400	2,89	2,40	6,93	-2,90	-8,37	-0,50	-1,44
1200 - 1300	15,02	2,75	41,31	-3,05	-45,81	-0,30	-4,51
1100 - 1200	26,23	2,75	72,14	-3,20	-83,95	-0,45	-11,81
1000 - 1100	8,91	1,95	17,37	-3,50	-31,18	-1,55	-13,81
900 - 1000	5,16	0,88	4,55	-4,50	-23,24	-3,62	-18,70
800 - 900	1,91	0,44	0,84	-5,50	-10,49	-5,06	-9,65
700 - 800	0,95	0,29	0,27	-6,50	-6,16	-6,21	-5,88
600 - 700	0,38	0,20	0,08	-7,50	-2,83	-7,30	-2,76
520 - 600	0,22	0,15	0,03	-8,40	-1,88	-8,25	-1,85
Calving					-7,2		-7,2
520 - 1580	62,4	2,33	145,2	-3,58	-223,2	-1,25	-78,0

Table 11-1
Specific (left) and volume (right) winter, summer, and net balance calculated for 100 m elevation intervals for Storglombreen 2002.

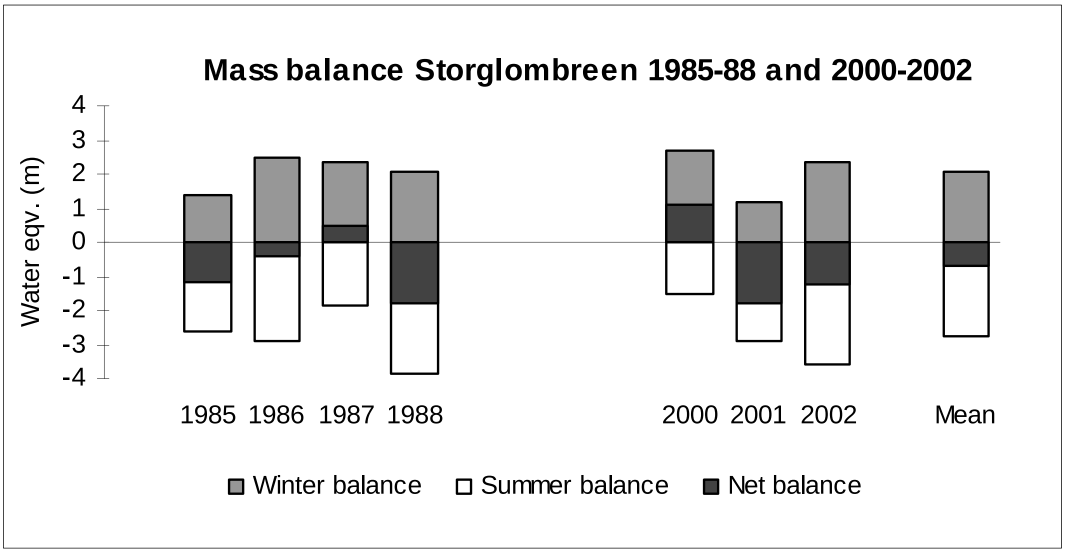


Figure 11-4
Mass balance at Storglombreen during the period 1985-1988 and 2000-02.

11.3 Front position change

Storglombreen has three distinct front segments that calve into lake Storglomvatnet (Fig. 11-1). Observation of front position changes began in 2000, and will be continued in order to document changes associated with changes in the water level of the reservoir. The front of the calving outlet from glacier Tretten-null-to-breen is observed also (Fig. 11-1).

The terminus position was measured on 26th September from STO101 using Terskaldfjellet as a reference point (Fig. 11-5). A Geodimeter total station and eight reflectors located in the helicopter window were used. The terminus was positioned by observing the reflectors as the helicopter touched the ice edge, if possible, along the front perimeter. The accuracy of this method depends on the geometry of the glacier front and the flight conditions, and such measurements may therefore be relatively uncertain. Horizontal uncertainty of individual points is estimated to be less than ±2 m, while vertical uncertainty is much less when the helicopter touches the ground. Figure 11-5 shows the observations, and the observed terminus position in 1985 and 1968**.** At the time of the field visit, the lake level was 584 m a.s.l., close to the highest level at 585 m a.s.l**.**

Tretten-null-to-breen

The 150 m long terminus was defined by measuring three points. The terminus has retreated about 20 m between 2000 and 2002.

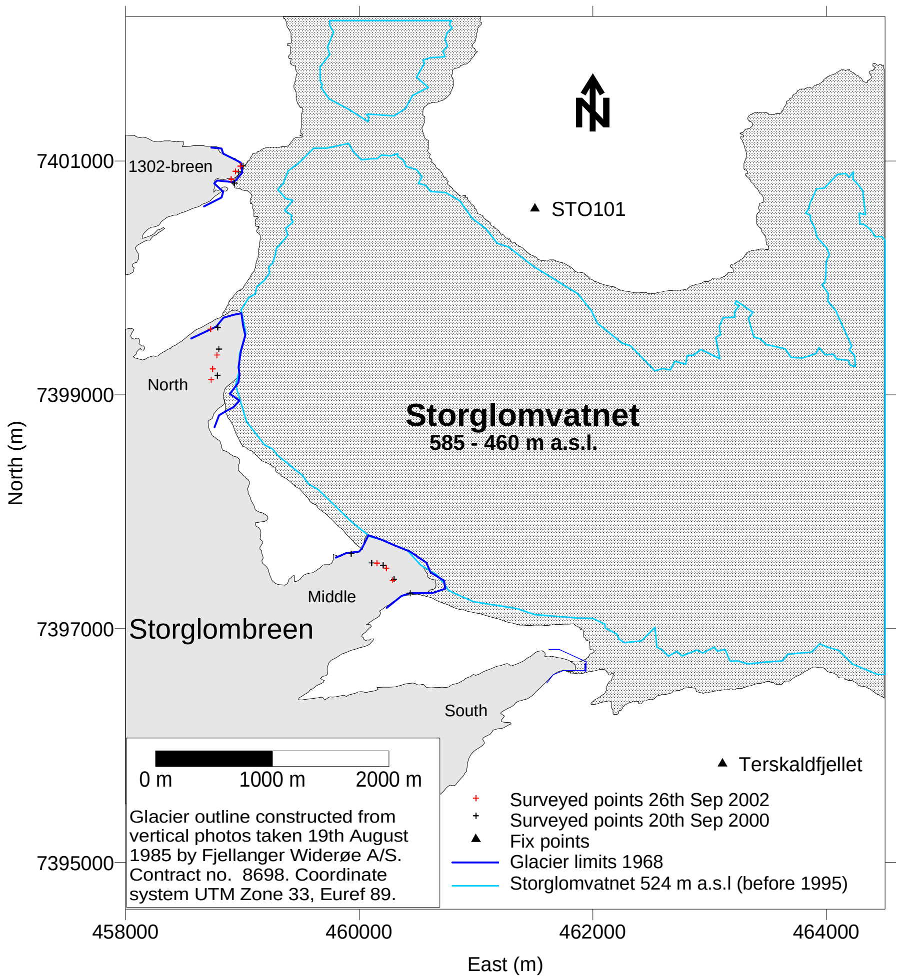


Figure 11-5
Front position changes of the termines that calve into the Storglomvatnet reservoir.

North Storglombreen

The 400 m long terminus was defined by measuring four points. The front retreated about 30 m between 2000 and 2002.

Middle Storglombreen

The terminus was defined by measuring three points. No significant changes were recorded.

South Storglombreen

This glacier tongue is not visible from STO101. The glacier terminated in the lake. Comparison of photographs from 2000 and 2002 imply that no significant changes have taken place.

12. Rundvassbreen (Rune V. Engeset)

Rundvassbreen (Fig. 12-1) is a 11.6 km^2 north-eastern outlet glacier of the icecap Blåmannsisen (67°20'N, 16°05'E), which at 87 km^2 is the 5th largest glacier in Norway. Rundvassbreen extends from 1536 m a.s.l. down to 788 m a.s.l. Rundvassbreen is the glacier outlet that drains past Lake Vatn 1051, from which a jøkulhlaup in September 2001 drained about 40 million cubic metres of water under the glacier. The event called for a study of the glacier and the jøkulhlaup by the hydropower company Elkem ASA. The observations in 2002 include mass balance, lake level change of Vatn 1051 and ice surface displacement (Engeset, 2002).

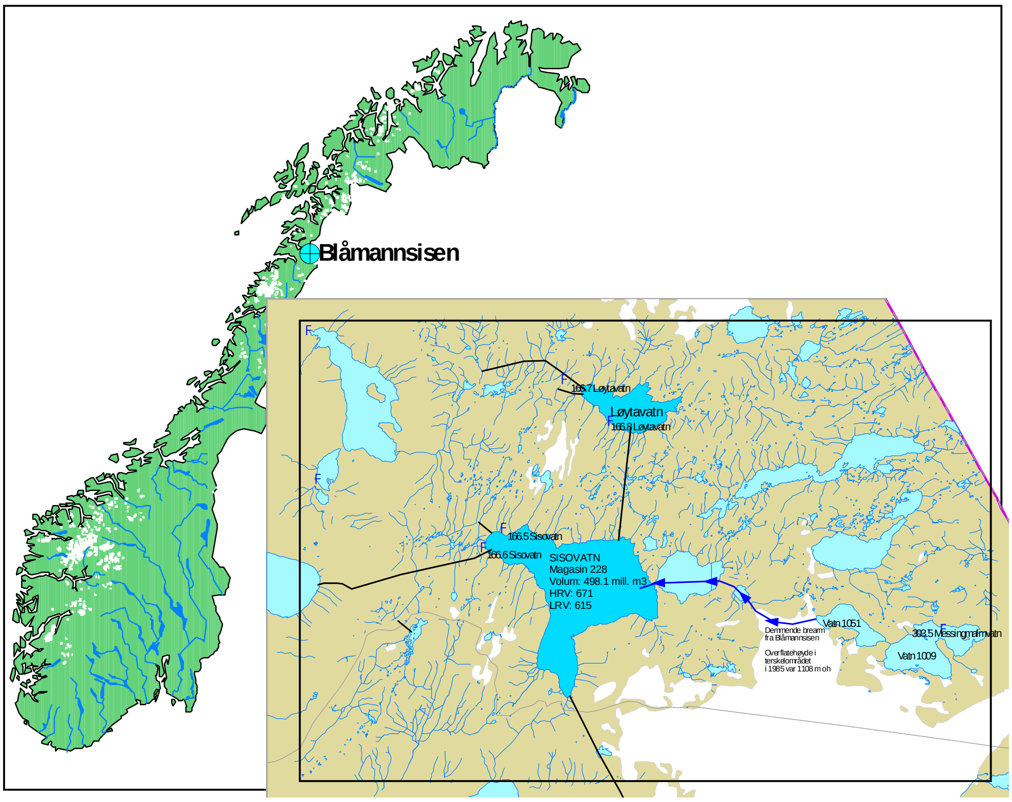


Figure 12-1
Map of area. The drained lake and the course of the water is shown.

12.1 Mass balance 2002

Fieldwork

Snow accumulation measurements were carried out 22nd May, when a stake network of 7 stakes was established. Calculation of winter balance is based on (Fig. 12-2):

- Cores samples drilled at all 7 stake positions to identify summer surface. Stakes are at following elevations: 966 (stake 10), 1112 (stake 20), 1174 (stake 30), 1275 (stake 40), 1333 (stake 50), 1395 (stake 60), and 1525 (stake 70) m a.s.l.

- Snow depth measured at 125 locations spaced at 200-m distances along a 22 km profile. Identification of the summer surface was difficult above 1400 m a.s.l. Snow depth was about 5-7 m above 1300 m a.s.l., 4-5 m between 1200 and 1300 m a.s.l, and 2-3 m below 1200 m a.s.l.
- Snow density measured to 5.17 m depth (SS at 5.15 m) at stake 50 (1333 m a.s.l.)

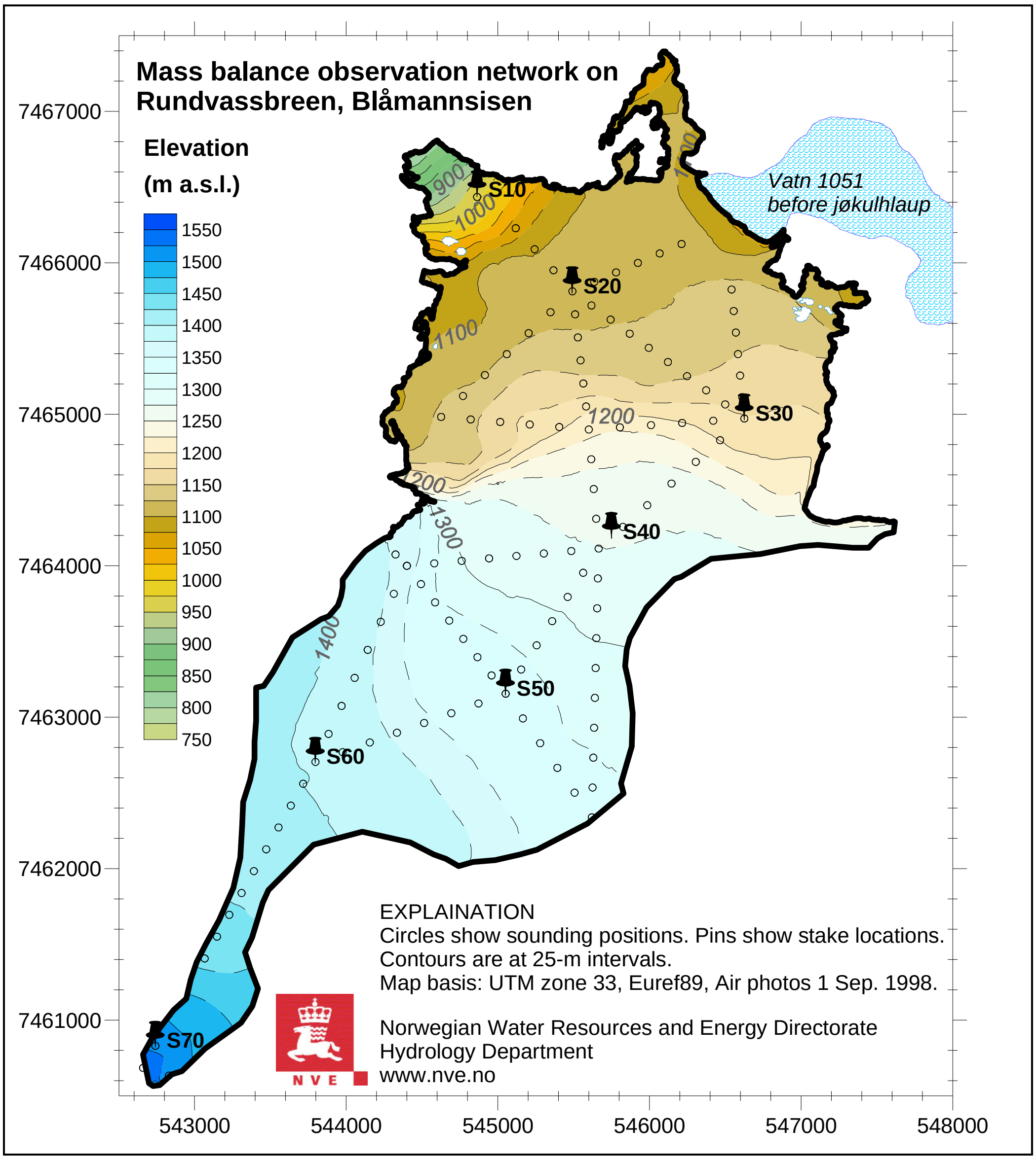


Figure 12-2
Location of stakes/cores, density pit and sounding profiles at Rundvassbreen in 2002.

Ablation measurements were carried out on 18th and 19th September. Measurements were made at the 7 stakes. No winter snow was observed below stake 40 (1275 m a.s.l.). At stake 50 (1333 m a.s.l.), 0.35 m of winter snow was observed. A very thin cover of fresh snow covered the glacier, and thus the equilibrium line altitude was estimated as 1300 m a.s.l. based on the stake measurements only.

Results

Winter balance

The calculation of winter balance is based on point measurements of snow depth (125 soundings and 7 core drillings) and snow density at one location (Fig. 12-3).

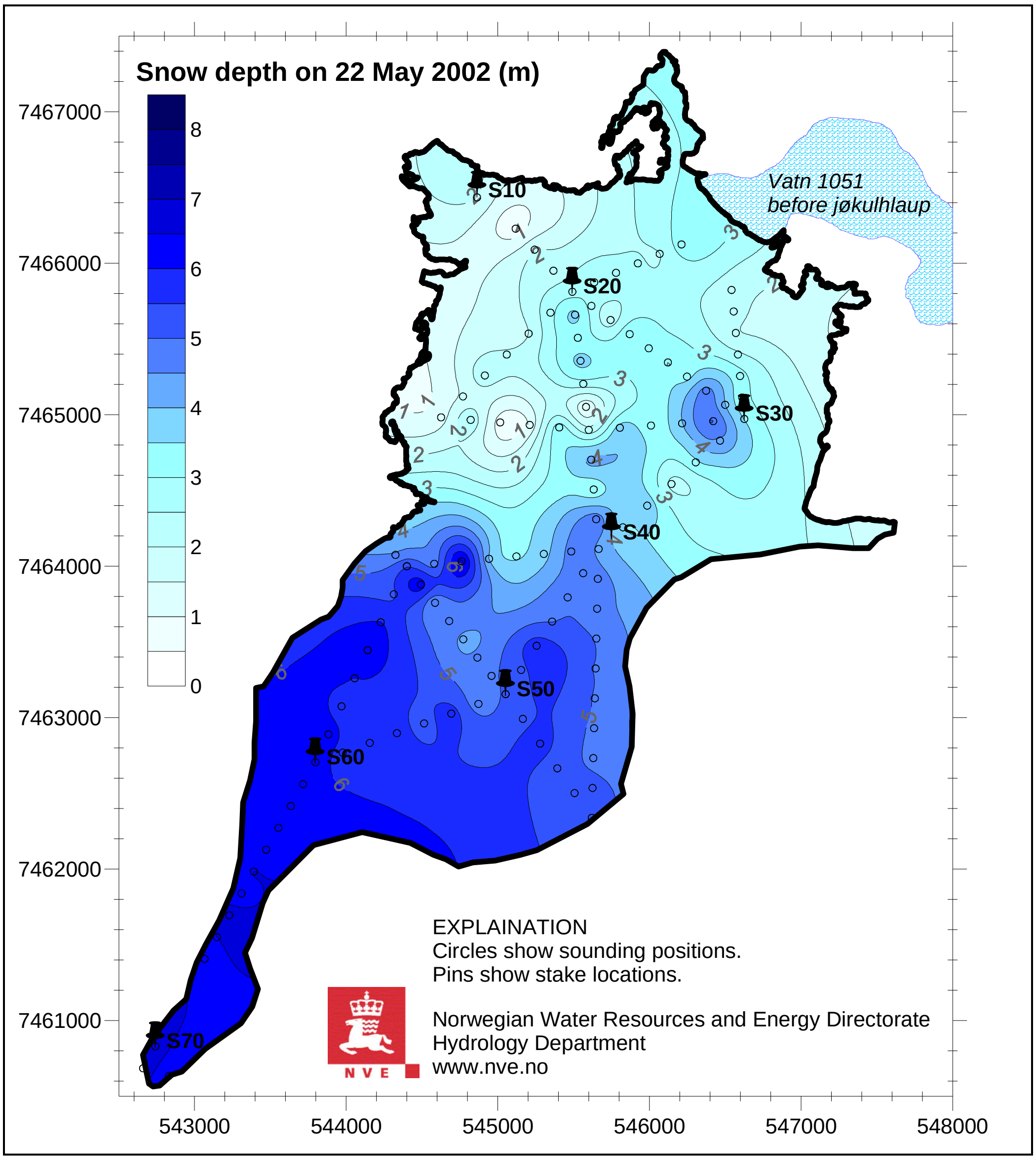


Figure 12-3
Snow depth at Rundvassbreen 2002 interpolated from 125 soundings and 7 cores.

Snow density measured at 1330 m a.s.l. (5.17 m depth). The depth profile showed no change in density as a function of depth, rather a constant density of 510 kg m^{-3}, which was used to convert snow depth to water equivalent values.

The winter balance calculation was performed by plotting measurements (water equivalent) in a diagram. A curve was drawn based on visual evaluation, and a mean value for each 50 m height interval estimated (Tab. 12-1). This gives a *winter balance* of 2.1 m w.eqv., corresponding to a water volume of 25 mill. m^3.

The winter balance was also interpolated based on the distribution of snow depth measurements (Fig. 12-4). The result based on this method, which is a control of the traditional method, showed a *winter balance* of 2.0 m w.eqv.

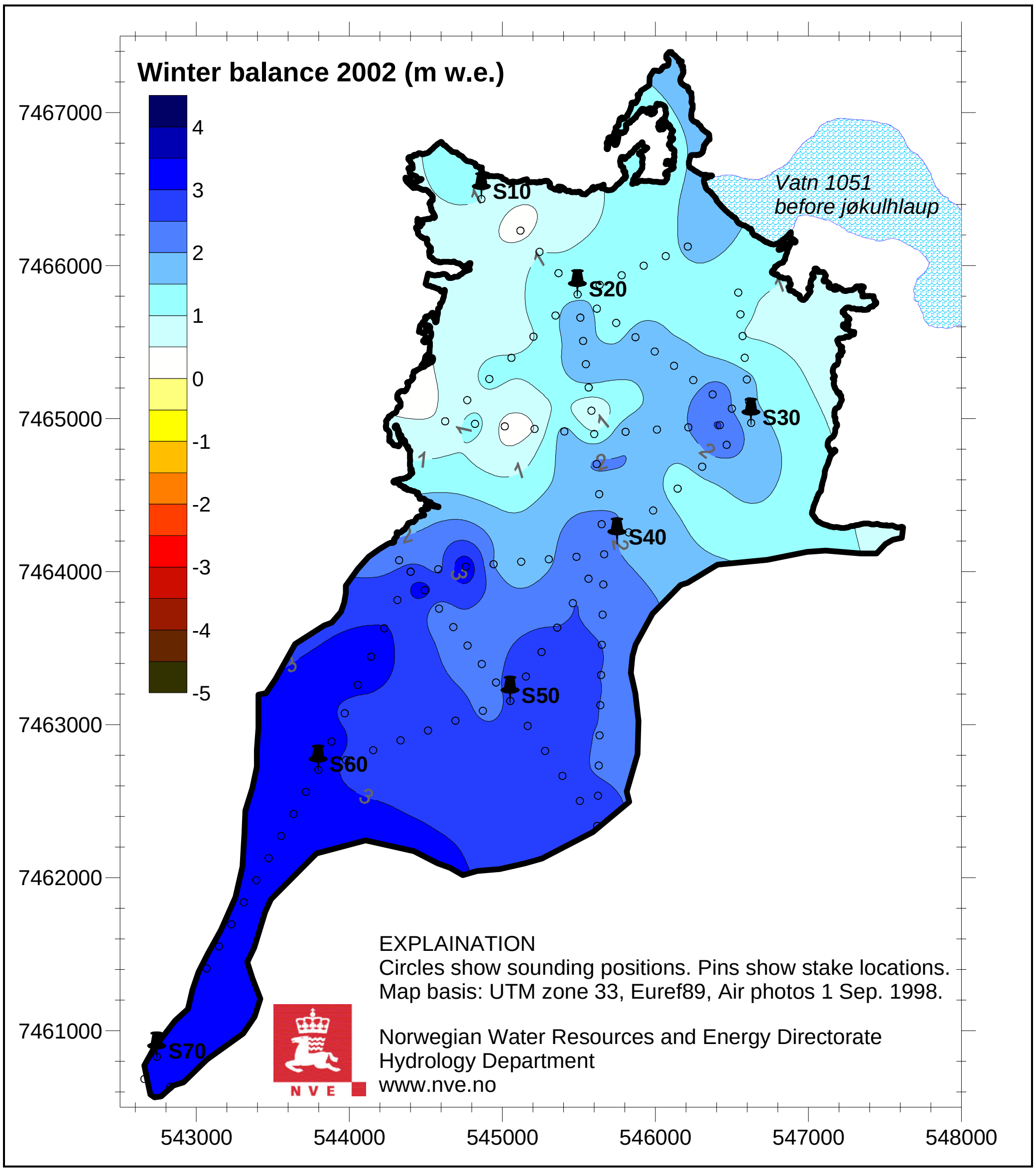


Figure 12-4
Winter balance at Rundvassbreen in 2002 interpolated from 132 measurements.

Summer balance

When calculating the summer balance the density of the remaining snow was estimated as 600 kg m^{-3}, and the density of melted ice as 900 kg m^{-3}.

The summer balance was calculated at 7 stakes, and increased from about -2.3 m w.eqv. at the glacier summit to more than -4.5 m down on the tongue. Based on estimated density and stake measurements the *summer balance* was calculated to be -3.2 m w.eqv., which is -37 mill. m^3 of water.

Net balance

The net balance was calculated at the 7 stake positions. The *net balance* was calculated as -1.1 m w.eqv., which equals a deficit of 12 mill.m^3 water.

The diagram in Figure 12-5 indicates that the equilibrium line altitude (ELA) was 1323 m a.s.l. Accordingly, the Accumulation Area Ratio (AAR) was 23 %.

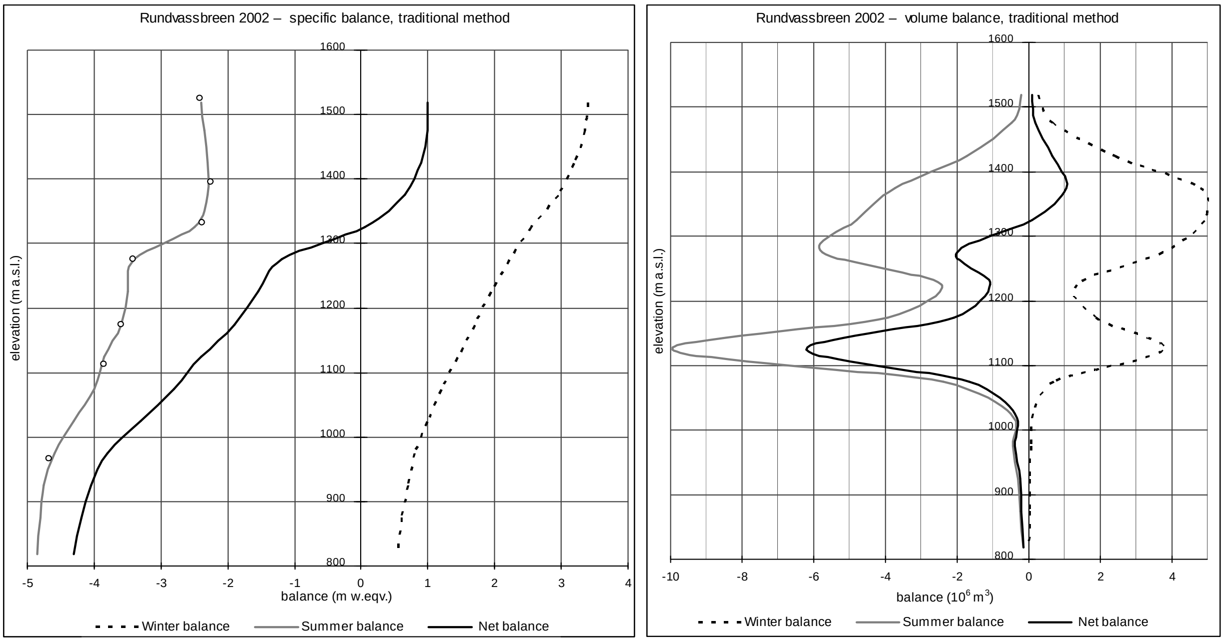


Figure 12-5
Specific balance (left) and volume balance (right) for Rundvassbreen 2002.

Mass balance Rundvassbreen2001/02 – traditional method

Altitude (m a.s.l.)	Area (km^2)	Winter balance, Measured 24th Mauy 2002: Specific (m w.eq.)	Winter balance: Volume (10^6 m^3)	Summer balance, Measured 18th Sep 2002: Specific (m w.eq.)	Summer balance: Volume (10^6 m^3)	Net balance, Summer surfaces 2001 - 2002: Specific (m w.eq.)	Net balance: Volume (10^6 m^3)
1500 - 1537	0,09	3,40	0,3	-2,40	-0,2	1,00	0,1
1450 - 1500	0,20	3,35	0,7	-2,35	-0,5	1,00	0,2
1400 - 1450	0,75	3,20	2,4	-2,30	-1,7	0,90	0,7
1350 - 1400	1,62	2,95	4,8	-2,30	-3,7	0,65	1,1
1300 - 1350	1,92	2,55	4,9	-2,50	-4,8	0,05	0,1
1250 - 1300	1,69	2,22	3,8	-3,40	-5,8	-1,18	-2,0
1200 - 1250	0,70	1,95	1,4	-3,50	-2,4	-1,55	-1,1
1150 - 1200	1,09	1,70	1,9	-3,60	-3,9	-1,90	-2,1
1100 - 1150	2,58	1,45	3,7	-3,85	-9,9	-2,40	-6,2
1050 - 1100	0,59	1,20	0,7	-4,00	-2,4	-2,80	-1,7
1000 - 1050	0,12	1,00	0,1	-4,30	-0,5	-3,30	-0,4
950 - 1000	0,10	0,80	0,1	-4,60	-0,4	-3,80	-0,4
900 - 950	0,06	0,70	0,0	-4,75	-0,3	-4,05	-0,2
850 - 900	0,05	0,60	0,0	-4,80	-0,2	-4,20	-0,2
788 - 850	0,03	0,55	0,0	-4,85	-0,1	-4,30	-0,1
788-1537	**11,6**	**2,14**	**24,7**	**-3,19**	**-37,0**	**-1,05**	**-12,2**

Table 12-1
Winter, summer and net balance for Rundvassbreen in 2002.

12.2 Glacier change 1961-1998

Maps of the glacier surface elevation and extent were constructed from aerial photographs acquired on 30th August 1961 and 1st September 1998. These maps were used for analysis of glacier area and volume changes over this 37-year period.

Area change

The glacier snout retreated about 1.2 km during the last century, between the Little Ice Age maximum and 1985, since when the glacier front has been at the same location. A 200-m retreat was observed from 1961 to 1985 at the snout. The calving front in lake Vatn 1051 retreated 130-300 m, which effectively increased the lake area from 0.16 to 1.26 km^2 (Fig. 12-6).

Volume change

The glacier maps provide surface elevation at 10-m intervals. The analysis shows surface elevation increased above 1250 m a.s.l. (the long-term equilibrium line), and surface lowering at lower elevations, ranging from +38 to -52 m (Fig. 12-7). There was an increase in glacier surface elevation over an area of 5.6 km^2. Assuming constant firn density in 1961 and 1998, volume change was derived by multiplying change in elevation by the density of ice (900 kg m^{-3}). The calculation shows a loss of 2.4 m w.eqv. per area unit (a water volume loss of 28.5 mill. m^3). The glacier was almost in an state of equilibrium, but changed geometry becoming steeper.

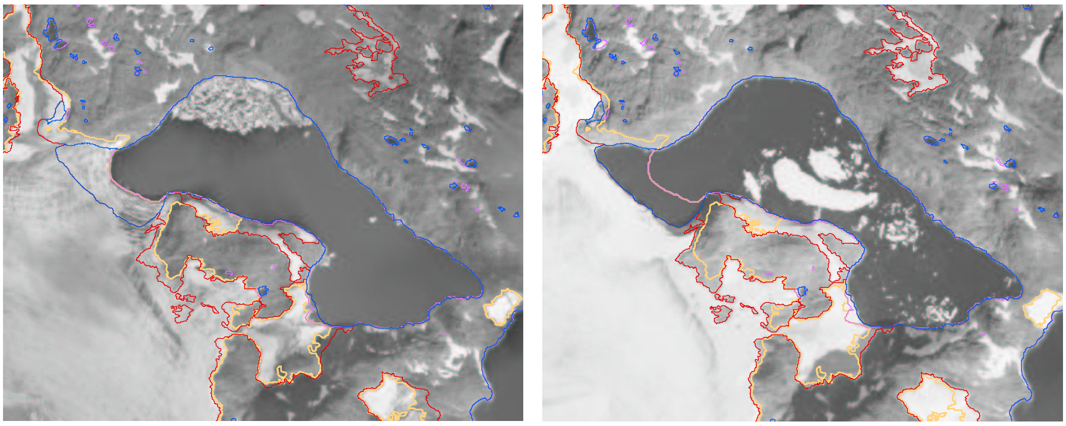


Figure 12-6
Aerial photos from 1961 (left) and 1998 (right) of Lake Vatn 1051 in 1961 (magenta line) and 1998 (blue line), and glacier front in 1961 (yellow) and 1998 (red). Photos: Fjellanger Widerøe.

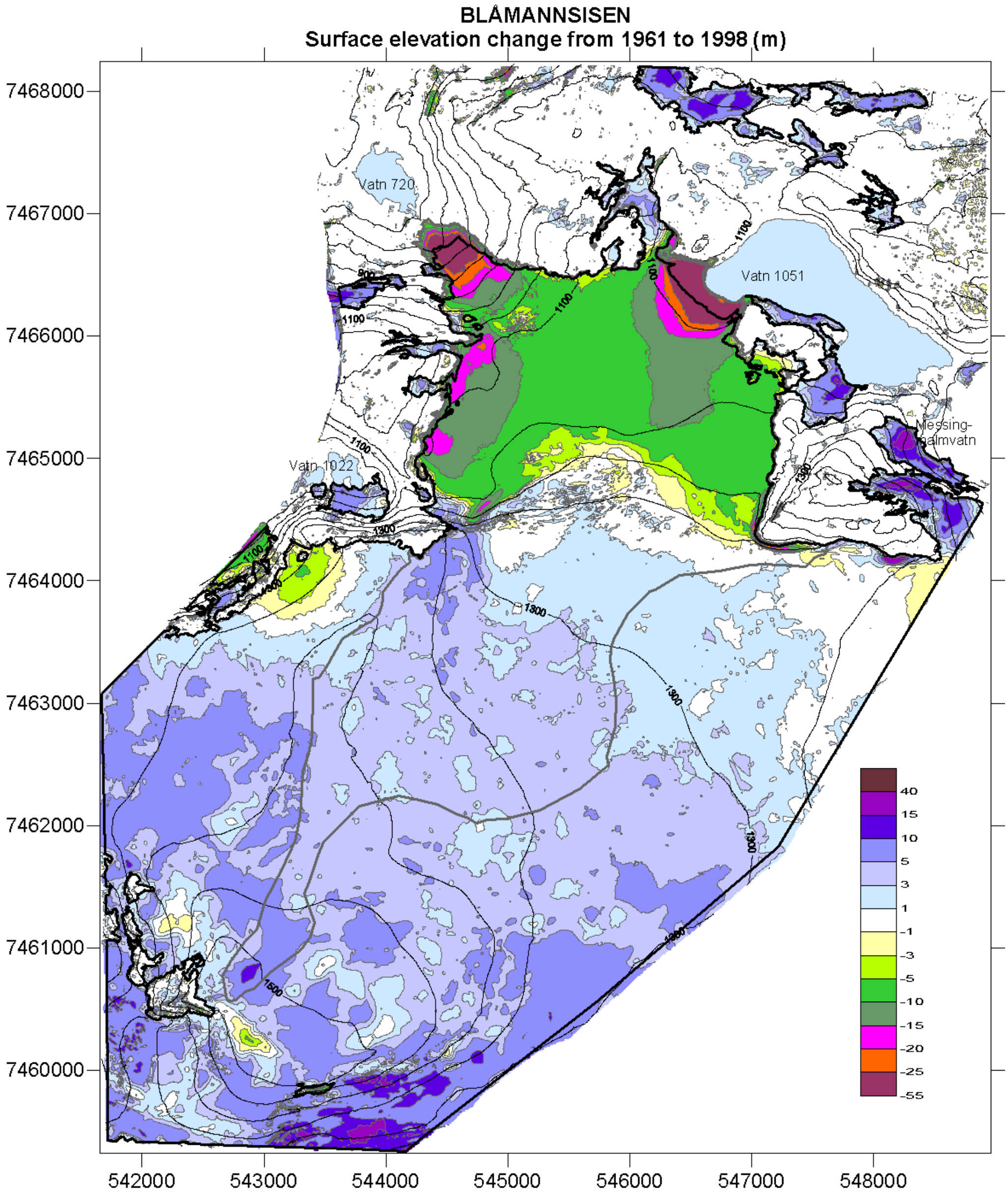


Figure 12-7
Map of surface elevation change 1961-1998 (m). Map shows 50-m contours from 1998.

13. Langfjordjøkelen (Bjarne Kjøllmoen)

Langfjordjøkelen (70º10'N, 21º45'E) is a plateau glacier situated on the border of Troms and Finnmark counties, approx. 60 km northwest of Alta. It has an area of about 8.4 km^2 (1994), and of this 3.7 km^2 drains eastward (Fig. 13-1). The investigations are performed on this east facing part, ranging from 280 to 1050 m a.s.l.

The glaciological investigations in 2002 include mass balance and change in front position. Langfjordjøkelen has been the subject of mass balance measurements since 1989 with the exception of 1994 and 1995.

Figure 13-1
The mass balance measurements are performed on the east-facing outlet (3.7 km^2). The photo was taken 12th of October 2002. Up to 1 meter of fresh snow had fallen at this time.
Photo: Bjarne Kjøllmoen.

13.1 Mass balance 2002

Fieldwork

Snow accumulation was measured on 21st May and the calculation of winter balance is based on (Fig. 14-2):

- Direct measurements of stakes at positions 10 (495 m a.s.l.) and 30 (890 m a.s.l.). It was also possible to make use of measurements of a substitute stake drilled in May 2002 and an older stake that appeared during the melt season in position 40 (1050 m a.s.l.).
- Core samples at positions 20 (665 m a.s.l.), 25 (745 m a.s.l.) and 40 (1050 m a.s.l.).

- 79 snow depth soundings along about 11 km of profiles between 330 and 1050 m a.s.l. The summer surface was distinct over the whole glacier. The snow depth varied between 4 and 5 m above 700 m altitude, and between 2 and 4 m below 700 m a.s.l.
- Snow density was measured down to 3.9 m depth (SS at 4.1 m) at 890 m altitude.

Location of stakes, density pit and sounding profiles are shown in Figure 13-2.

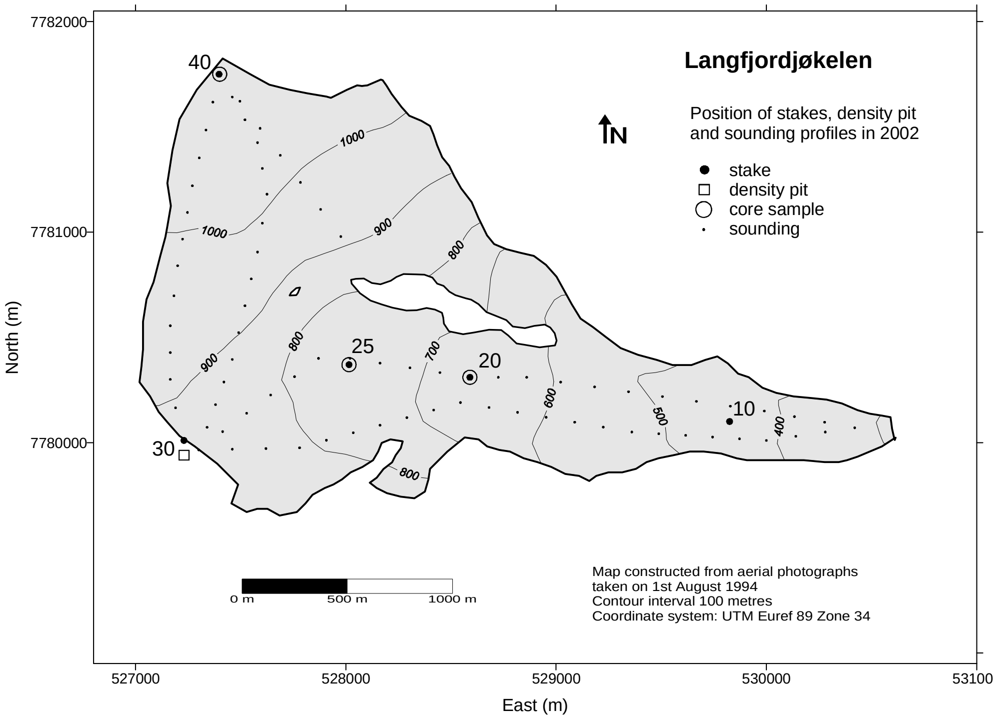


Figure 13-2
Locations of stakes, sounding profiles and density pit at Langfjordjøkelen in 2002.

Ablation was measured on 12th October. The net balance was measured directly at stakes in all five locations between 495 and 1050 m a.s.l. There was no snow remaining on the glacier from winter 2001/2002. Between 50 and 100 cm of fresh snow had fallen.

Results

The calculations are based on a glacier map from 1994.

Winter balance

The calculations of winter balance are based on several point measurements of snow depth (stakes and probings) and on one snow density measurement.

A density profile was modelled from the snow density measurement at 890 m altitude. The mean density of 4.1 m snow was 0.51 g/cm^3. The density model was used to convert all measured snow depths to water equivalents.

The winter balance calculations were performed by plotting the measurements (water equivalents) in a diagram. A curve was drawn based on visual evaluation (Fig. 13-4) and a mean value for each 100 m height interval estimated (Tab. 13-1).

The winter balance, thus, was calculated as 2.2 ±0.2 m w.eqv., corresponding to a water volume of 8 ±1 mill. m^3. The result is 98 % of the mean value for the periods 1989-1993 and 1996-2001.

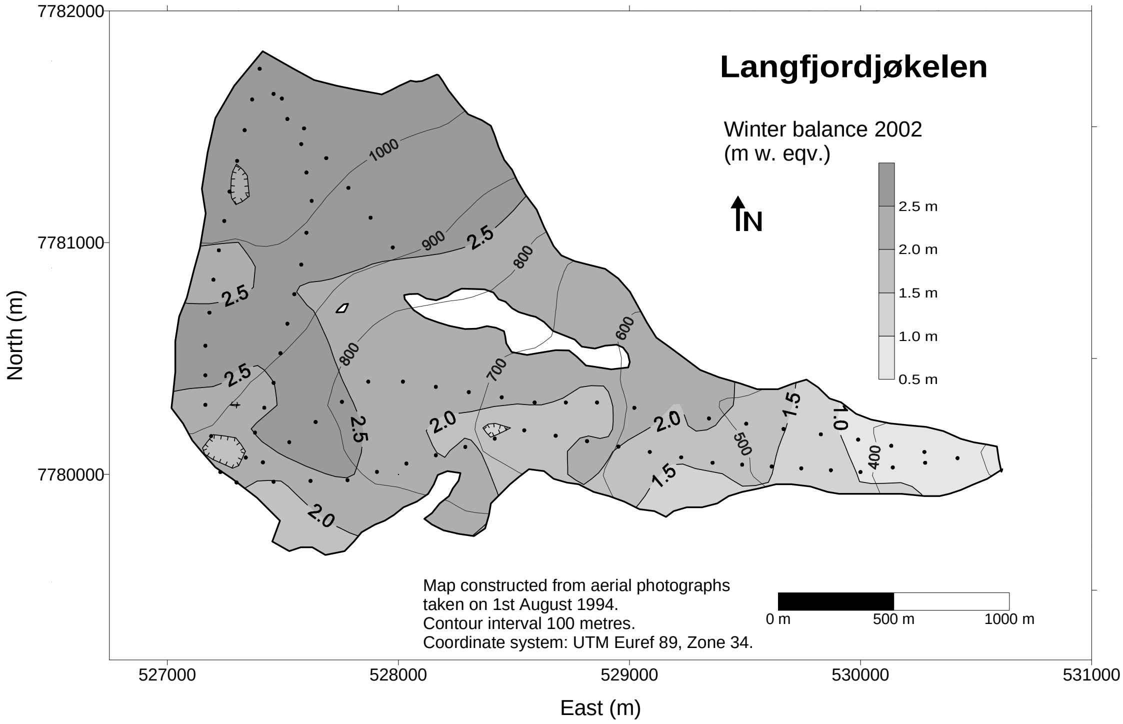


Figure 13-3
Winter balance at Langfjordjøkelen in 2002 interpolated from 79 snow depth measurements (•).

The winter balance was also calculated using a gridding method based on the aerial distribution of the snow depth measurements (Fig. 13-3). Water equivalents for each cell in a 100 x 100 m grid were calculated and summarised. The winter balance based on this method, which is a control of the traditional method, was also 2.2 m w.eqv.

Summer balance

The density of melted firn was estimated as 0.65 g/cm^3, while the density of melted ice was calculated as 0.90 g/cm^3.

The summer balance was measured and calculated at three stake positions, and increased from -2.9 m w.eqv. at 1050 m altitude to -4.7 m down on the glacier tongue (495 m a.s.l.). Based on estimated density and stake measurements, the summer balance was calculated to be -3.7 ±0.3 m w.eqv., which is -14 ±1 mill. m^3 of water. The result is 130 % of the average for the periods 1989-1993 and 1996-2001. This is the greatest summer loss since the measurements started in 1989.

Net balance

Hence, the net balance at Langfjordjøkelen for 2002 was -1.5 ±0.3 m w.eqv., which equals a volume loss of 6 ±1 mill. m^3 of water (Tab. 13-1). Figure 13-4 indicates that the equilibrium line altitude (ELA) was above the glacier summit (1050 m a.s.l.). Accordingly, the Accumulation Area Ratio (AAR) was 0 %. The accumulated negative net balance since 1989 is about 9 m water equivalent. Most of the deficit has occurred since 1996 (Fig. 13-5).

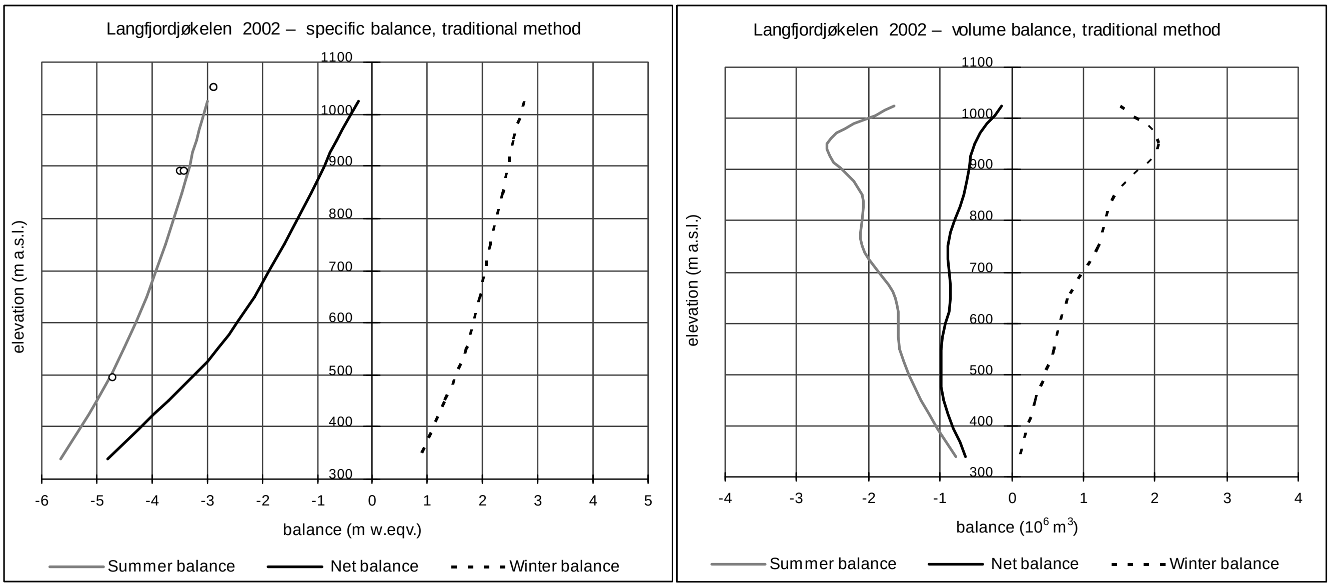


Figure 13-4
Mass balance diagram showing specific balance (left) and volume balance (right) for Langfjordjøkelen in 2002. Summer balance for stakes at three different sites is shown (o).

Mass balance Langfjordjøkelen 2001/02 – traditional method

Altitude (m a.s.l.)	Area (km^2)	Winter balance, Measured 24th May 2002: Specific (m w.eq.)	Winter balance: Volume (10^6 m^3)	Summer balance, Measured 12th Oct 2002: Specific (m w.eq.)	Summer balance: Volume (10^6 m^3)	Net balance, Summer surface 2001 - 2002: Specific (m w.eq.)	Net balance: Volume (10^6 m^3)
1000 - 1050	0,55	2,75	1,5	-3,00	-1,6	-0,25	-0,1
900 - 1000	0,81	2,55	2,1	-3,20	-2,6	-0,65	-0,5
800 - 900	0,61	2,35	1,4	-3,45	-2,1	-1,10	-0,7
700 - 800	0,56	2,15	1,2	-3,75	-2,1	-1,60	-0,9
600 - 700	0,39	1,95	0,8	-4,10	-1,6	-2,15	-0,8
500 - 600	0,35	1,70	0,6	-4,50	-1,6	-2,80	-1,0
400 - 500	0,25	1,30	0,3	-5,00	-1,3	-3,70	-0,9
280 - 400	0,14	0,85	0,1	-5,65	-0,8	-4,80	-0,7
280 - 1050	**3,65**	**2,19**	**8,0**	**-3,73**	**-13,6**	**-1,54**	**-5,6**

Table 13-1
Winter, summer and net balance for Langfjordjøkelen in 2002. Mean values for the periods 1989-93 and 1996-2001 are b_w=2,23 m, b_s=-2,88 m and b_n=-0,64 m w.eqv.

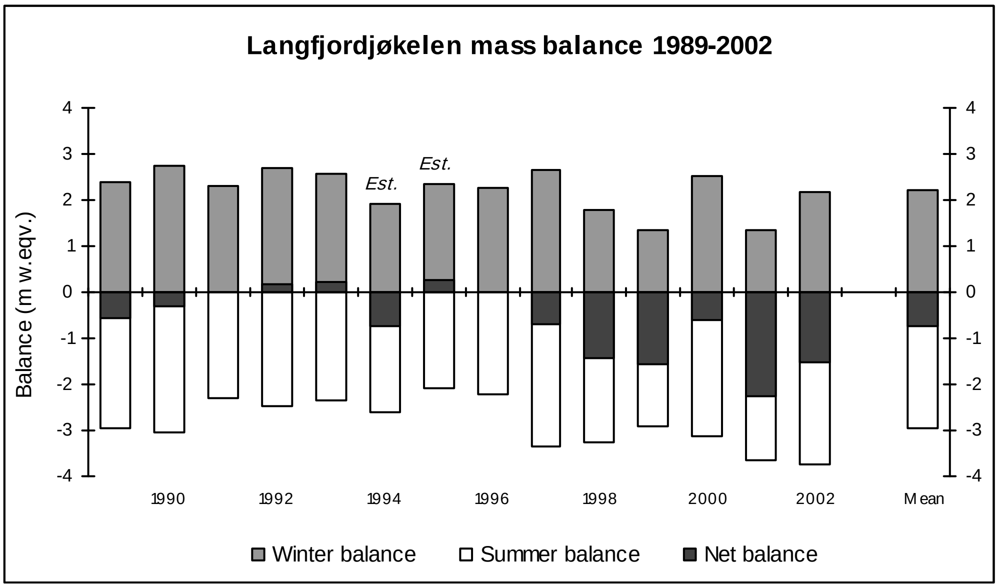


Figure 13-5
Mass balance at Langfjordjøkelen during the period 1989-2002. The accumulated deficit over 1989-2002 amounts to about 9 m water equivalents (included modelled values for 1994 and 1995).

13.2 Front position change

Annual measurements of the change in front position were initiated in 1998. The measurements are performed using traditional methods. The distance from the glacier terminus to marked control points is measured using measuring tape (Fig. 13-6). To enable comparison of results, the measurements are always performed in the autumn.

Due to fresh snow the front position could not be measured during the fieldwork in October 2001. However, measurements from August 2001 and October 2002 show a retreat in front position of 64 metres. The accumulated recession since July 1998 is 157 metres.

Figure 13-6
Changes in front position are determined using measuring tape from control points (marked boulders) to the glacier terminus. The photo shows the glacier terminus of Langfjordjøkelen in August 2002. Photo: Laila P.Høivik.

14. Glacier monitoring

(Liss M. Andreassen and Miriam Jackson)

14.1 Front position change

Observations of front position change have been made of Norwegian glaciers since the 1880s, but continuous measurements started around 1900.

In 2002 front position change was measured at 24 glaciers, 19 in southern Norway and 5 in northern Norway (Fig. 14-1).

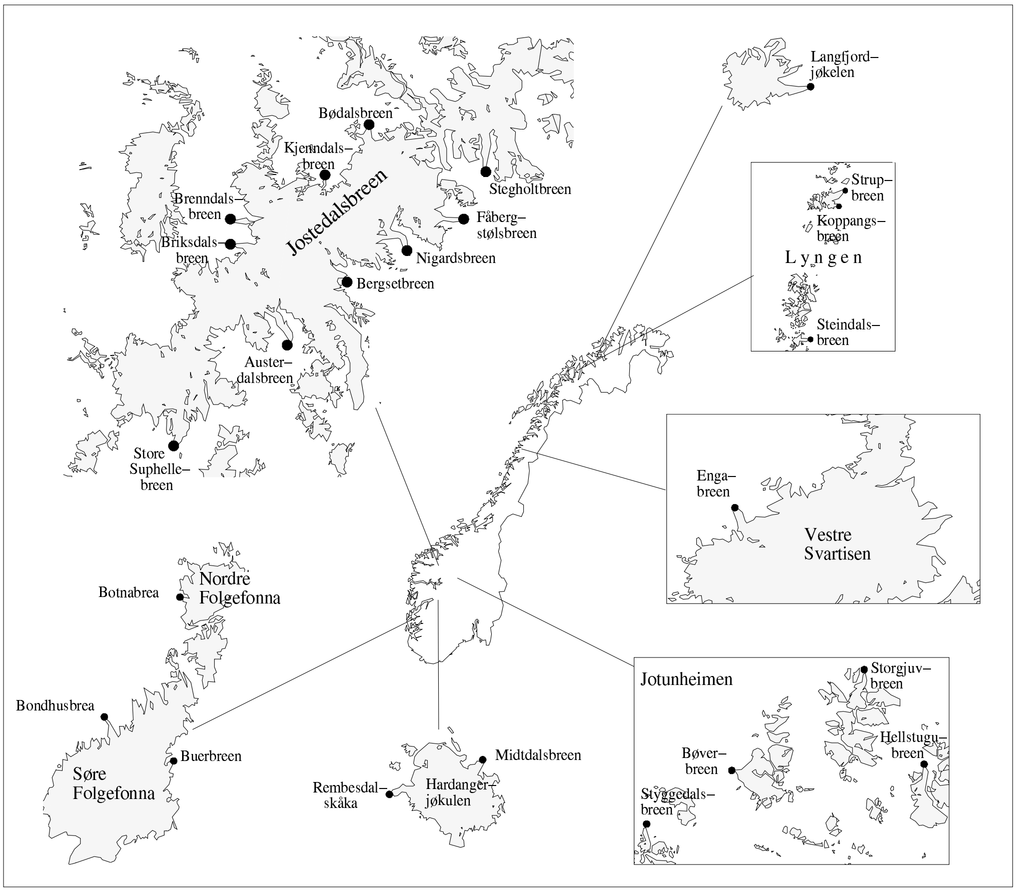


Figure 14-1
Location map showing glaciers where front position measurements were performed in 2002. Notice that the different glacier areas are not to the same scale.

Methods

The distance is measured from one or several established cairns or painted marks on rocks to the glacier front in defined directions, normally in September or October each year. Change in distance gives a rough estimate of the front fluctuations at one or more points at the glacier fronts. These measurements have a fairly high degree of uncertainty both in the actual length determination, and to what extent the measurement is representative for the entire glacier front. Nevertheless, the measurements give valuable information about glacier fluctuations and regional tendencies and variations when longer time periods are considered.

Results 2002

The front position changes from autumn 2001 to autumn 2002 at the observed glaciers are shown in Table 14-1. The main trend in Norway is glacier retreat. However, two of the glaciers had a noticeable net advance (defined as more than 2 m). Storgjuvbreen in Jotunheimen (Fig. 14-3) and Austerdalsbreen, an outlet from Jostedalsbreen, advanced 4 m and 5 m respectively.

Minor or no changes (between -2 and +2 m) were observed at 4 of the glaciers, while the remaining 18 glaciers, had noticeable negative changes in this period. In fact 16 of the 24 glaciers showed a net retreat in front position amounting to more than 10 m. Langfjordjøkelen had the largest observed retreat with 62 m (Fig. 14-2).

Area	Glacier	Change (m)	Measured by
Jostedalsbreen	Austerdalsbreen	5	NVE
	Bergsetbreen	-17	NVE
	Brenndalsbreen	-20	Universitet Trier, Germany
	Briksdalsbreen	-16	NVE
	Bødalsbreen	-2	Universitet Trier, Germany
	Fåbergstølsbreen	-28	NVE
	Kjenndalsbreen	-17	Universitet Trier, Germany
	Nigardsbreen	-1	NVE
	Stegholtbreen	-2	NVE
	Store Supphellebre	-28	Norwegian Glacier Museum
Folgefonna	Bondhusbrea	-15	Statkraft
	Botnabrea	-12	Statkraft
	Buerbreen	-2	NVE
Hardangerjøkulen	Midtdalsbreen	-26	University of Bergen
	Rembesdalskåka	-16	Statkraft
Jotunheimen	Bøverbreen	-6	Universitet Trier, Germany
	Hellstugubreen	-17	NVE
	Storgjuvbreen	4	Universitet Trier, Germany
	Styggedalsbreen	-24	NVE
Svartisen	Engabreen	-6	Statkraft
Lyngen	Koppangsbreen	-20	NVE
	Steindalsbreen	-51*	NVE
	Strupbreen	-14**	NVE
Finnmark	Langfjordjøkelen	-62	NVE

Table 14-1
Net front position change between autumn 2001 and autumn 2002 at 24 glaciers in Norway. See Figure 14-1 for location. *Change in front position is for two years (2000-2002). **Change in front position is for four years (1998-2002).

Figure 14-2
Langfordjøkelen in northern Norway had a pronounced retreat of 62 m from 2001 to 2002. Between 1998 (when measurements started) and 2002 the glacier retreated a total of 138 meters. Photo taken August 2002 by Laila P. Høivik.

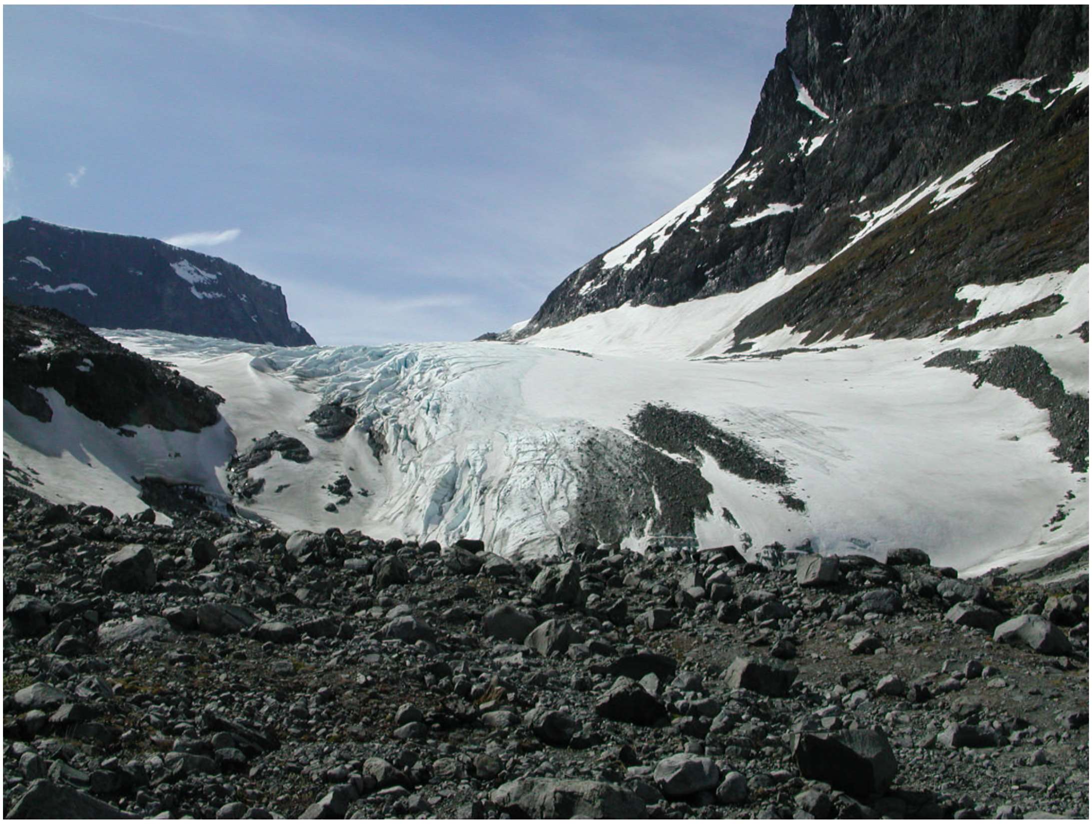


Figure 14-3
Storgjuvbreen in Jotunheimen has advanced over the last few years. The glacier has advanced 27 m since measurements of front position restarted in 1997. Photo taken June 2003 by Miriam Jackson.

Changes since 1980

Back in the 1980s, most of the observed glaciers were in a state of retreat (Fig. 14-4). In the 1990s, continental glaciers such as Hellstugubreen were still slowly retreating while an increasing number of glaciers started to advance, such as the maritime glaciers Nigardsbreen, Briksdalsbreen and Engabreen (Fig. 14-5). However, over the last three years, the number of advancing glaciers has declined rapidly.

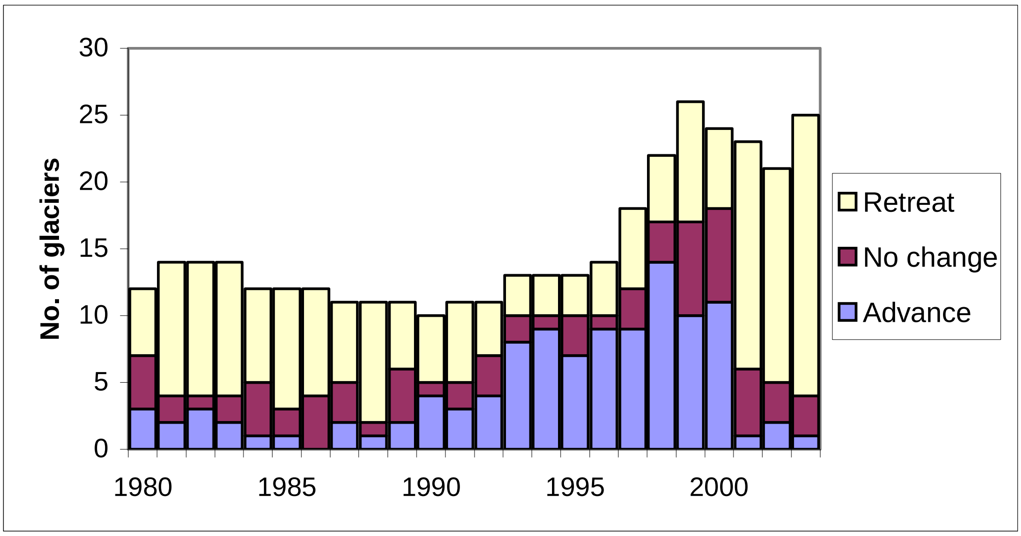


Figure 14-4
Diagram showing number of glaciers each year which have retreated (more than 2 m), show no change (between 2 m change) or have advanced (more than 2 m advance) since 1980.

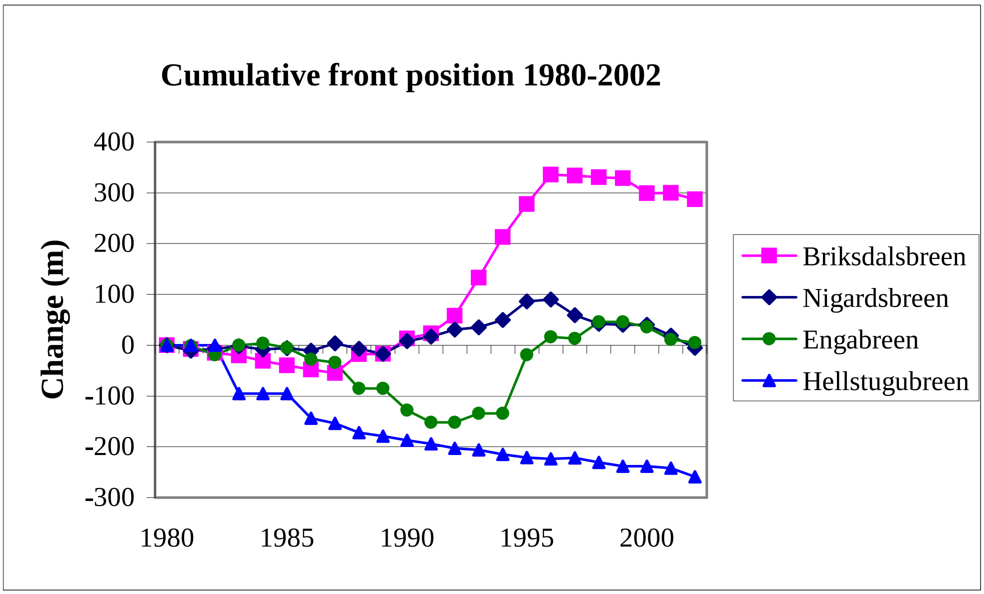


Figure 14-5
Cumulative front position since 1980 for selected glaciers. See Figure 14-1 for location. The continental valley glacier Hellstugubreen has slowly retreated during most of this period.

14.2 Monitoring of Baklibreen

Baklibreen (61°40′N, 7°05′E) is an outlet glacier of Jostedalsbreen. It has an area of 3 km^2 and covers an elevation range from 1950 m a.s.l. to about 1200 m a.s.l. An ice fall occurred from the glacier in the summer of 1986. The ice fell a total of 600-700 m and killed three tourists walking along the footpath below. The ice that fell is thought to have covered an area of 4000 m and to have had a total volume of 200 000 m^3. An observation programme was set up in 1987 to study the risk of future icefalls, and was in operation until 1999. A more limited monitoring programme has been in existence since 2000 and since 2001 this has been carried out as part of the European Union 5th Framework Glaciorisk project.

The footpath on which the tourists were killed is now inaccessible due to the recent advance of neighbouring glacier Bergsetbreen. The glacier front of Bergsetbreen advanced 360 m between 1984 and 1997 (Sorteberg, 1998), so Baklibreen is not such an immediate threat as it was. However, the glacier front retreated 30 m over the past two years so a footpath below Baklibreen may soon be accessible once again.

Photographs taken from the same point at approximately the same time of year in 2000 and 2002 are shown in Figure 14-6. These show fairly dramatic changes over this two year period, and suggest a fair amount of ice loss.

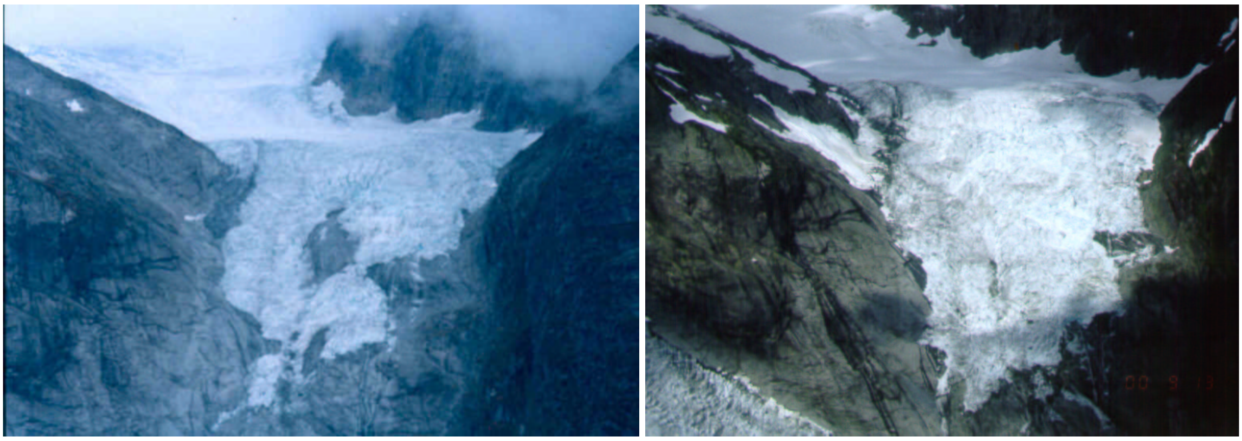


Figure 14-6
Baklibreen, October 2002, on the left, and September 2000, on the right.
Photos: Bjarne Kjøllmoen.

A comparison of aerial photographs from 1964 and 1984 show that ice thickness decreased significantly over most of the glacier over this period. A comparison of glacier surface measurements done in 1989 with the 1984 aerial photographs show little change in this period. The biggest increase took place in the period between 1989 and 1994 when ice thickness increased between 10 m and 20 m on the surveyed part of the glacier (area below 1300 m a.s.l.). A slight increase was measured between 1994 and 1996, and little change was registered between 1996 and 1999. More detailed information on these measurements is available in Kjøllmoen (ed.) (2000).

Survey points on the glacier in 2001 and 2002 are shown in Figure 14-7. Measurements on Baklibreen since 1993 have been made from a survey point established on a nearby prominent rock outcrop, and sightings are then made with a GDM to different points on the glacier. These points are visited by helicopter, and prisms are used for sighting. For points that are coincidental for both years, there is a change in elevation of between 3 and 6 m, with the 2002 points having the lower elevation. For those survey points that are not exactly coincident in both years, an interpolated elevation is used. The 2001 survey was performed on 19th September, and the 2002 survey was performed on 8th October. Hence, some of the lower elevations may be explained by extra melting due to the later survey date.

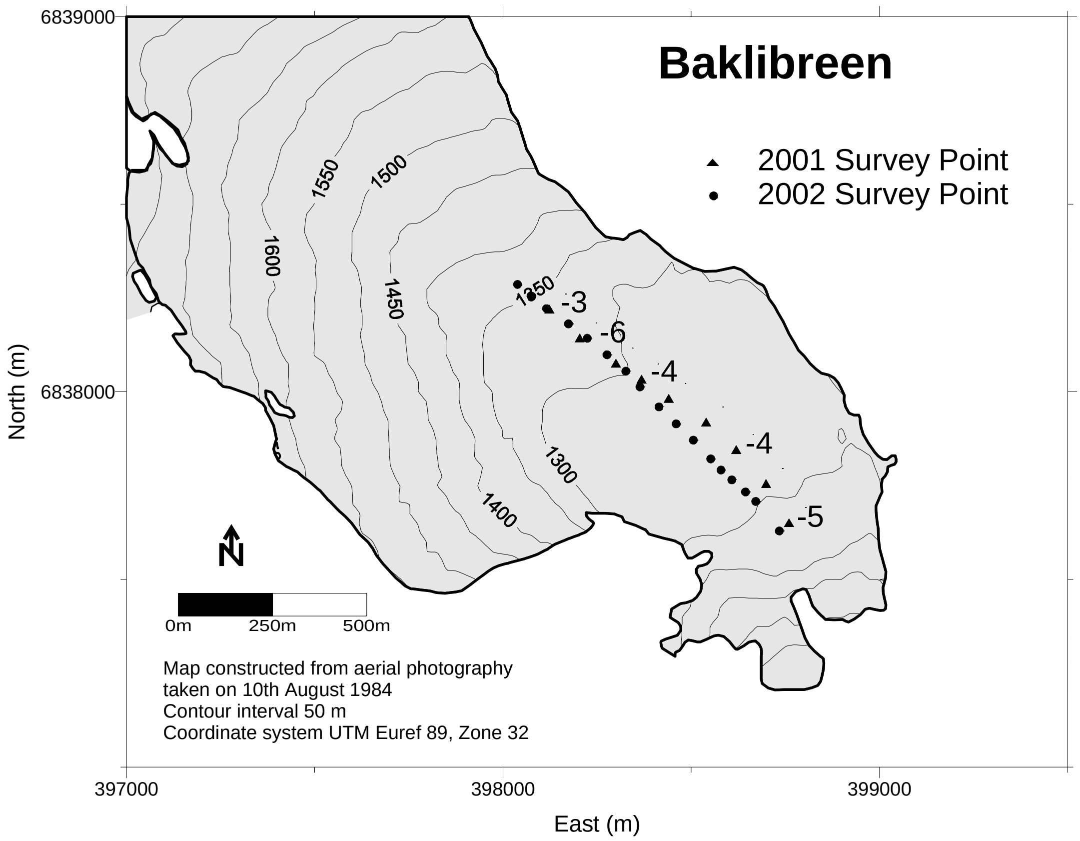


Figure 14-7
Map of Baklibreen showing survey points on the glacier in 2001 and 2002.

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Appendix A

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Using aerial photography to study glacier changes in Norway. *Reprint No. 127 from Annals of Glaciology 34 2002*, p. 343-348.

Cohen, D., N.R. Iverson, T.S. Hooyer, U.H. Fischer, M. Jackson and P.L. Moore
Importance of debris-bed friction in resisting sliding of a hard-bedded glacier. EGS-AGU-EUG Joint Assembly, 6 - 11 April 2003, Nice, France.

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Jøkulhlaup ved Blåmannsisen. Jøkulhlaupet 2001 og fremtidige jøkulhlaup. *NVE Oppdragsrapport 9 2002*, 47 s.

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Scenarios of annual and seasonal runoff for Norway. *NVE Oppdragsrapport 10 2002*, 56 s.

Appendix B

Mass balance measurements in Norway – an overview

During the period 1949-2002 there are carried out mass balance measurements at 42 Norwegian glaciers. The table below shows some characteristic data for the individual glaciers.

Area/ No. Glacier	No. of REGINE	Area (km^2)	Altitude (m a.s.l.)	Period	No. of years
Ålfotbreen					
1 Ålfotbreen	086.6C1B	4.5	903-1382	1963-	40
2 Hansebreen	086.6E	3.1	930-1327	1986-	17
Folgefonna					
3 Blomsterskardsbreen	042.G	45.7	850-1640	1970-77	8
4 Bondhusbrea	046.3C	10.7	480-1635	1977-81	5
5 Breidablikkbrea	046.3B	3.9	1219-1660	1963-68	6
6 Gråfjellsbrea	046.32B	9.4	1039-1660	1964-68, 1974-75	7
7 Blåbreen and Ruklebreen	048.4Z/048.B1	4.5	1065-1610	1963-68	6
8 Midtre Folgefonna	046.4B3C/048.32	8.7	1100-1570	1970-71	2
Jostedalsbreen					
9 Jostefonn	078.5Z	3.8	960-1622	1996-2000	5
10 Vesledalsbreen	088.B1Z	4.2	1130-1730	1967-72	6
11 Tunsbergdalsbreen	076.BC	50.1	540-1930	1966-72	7
12 Nigardsbreen	076.EZ	47.8	320-1960	1962-	41
13 Store Supphellebreen	078.2AZ	12.0	80-300/ 720-1740	1964-67, 1973-75, 1979-82	11
14 Austdalsbreen	076.H	11.8	1200-1757	1988-	15
15 Spørteggbreen	075.4Z/076.Z	27.9	1260-1770	1988-91	4
16 Harbardsbreen	075.DC	13.2	1250-1960	1997-2001	5
Hardangerjøkulen					
17 Rembesdalskåka	050.4C1Z	17.1	1020-1865	1963-	40
18 Omnsbreen	012.CK3	1.5	1460-1570	1966-70	5
19 Midtdalsbreen	012.CK2	6.7	1380-1862	2000-2001	2
Jotunheimen					
20 Tverråbreen	002.DHBAZ	5.9	1415-2200	1962-63	2
21 Blåbreen	002.DGEB	3.6	1550-2150	1962-63	2
22 Storbreen	002.DHBBZ	5.4	1390-2100	1949-	54
23 Vestre Memurubre	002.DGG1Z	9.0	1570-2230	1968-72	5
24 Austre Memurubre	002.DGG1Z	8.7	1630-2250	1968-72	5
25 Hellstugubreen	002.DHBAZ	3.0	1480-2210	1962-	41
26 Gråsubreen	002.DGDC	2.3	1830-2290	1962-	41
Svartisen					
27 Charles Rabot Bre	155.D4Z	1,1	1090-1760	1970-73	4
28 Austre Okstindbre	155.4G	14.0	730-1750	1987-96	10
29 Høgtuvbreen	156.CCAZ	2.6	590-1170	1971-77	7
30 Svartisheibreen	156.CE	5.5	770-1420	1988-94	7
31 Engabreen	159.81	38.0	40-1594	1970-	33
32 Storglombreen	160.C	59.0 62,4	520-1580 520-1580	1985-88 2000-	7
33 Tretten-null-tobreen	160.C	4.3	580-1260	1985-86	2
34 Glombreen	160.3Z	2.2	870-1110	1954-56	3
35 Kjølbreen	156.CG	3.9	850-1250	1954-56	3
36 Trollbergdalsbreen	161.F	1.8 1.6	900-1375 900-1300	1970-75 1990-94	11
Blåmannsisen					
37 Rundvassbreen	166.DZ	11.6	788-1537	2002-	1
Skjomen					
38 Blåisen	174.30	2.2	850-1200	1963-68	6
39 Storsteinsfjellbreen	173.AB6Z	6.1 5.9	920-1850 970-1850	1964-68 1991-95	10
40 Cainhavarre	173.AZ	0.7	1210-1540	1965-68	4
Vest-Finnmark					
41 Svartfjelljøkelen	211.34C	2.7	500-1080	1978	1
42 Langfjordjøkelen	211.33Z	3.7	280-1050	1989-93, 1996-	12

Appendix C

Mass balance measurements in Norway – annual results

There are results from 501 years of measurements at Norwegian glaciers. The following tables show winter (bw), summer (bs) and net balance (bn) together with cumulative net balance (Cum. bn) and equilibrium line altitude (ELA) for every single year at each glacier. In front of each table there is a heading containing the name and the area of the glacier. The reported year (in brackets) corresponds to the given area.

1 Ålfotbreen - 4.5 km^2 (1997)

No. of	Year	bw	bs	bn	Cum. bn	ELA
years		(m w.eqv.)		(m w.eqv.)		(m a.s.l.)
1	1963	2,48	-3,58	-1,10	-1,10	1300
2	64	2,69	-2,41	0,28	-0,82	1140
3	65	3,64	-3,16	0,48	-0,34	1150
4	66	2,47	-4,08	-1,61	-1,95	>1380
5	67	4,46	-3,18	1,28	-0,67	950
6	68	4,55	-3,60	0,95	0,28	1075
7	69	2,66	-4,83	-2,17	-1,89	>1380
8	1970	2,60	-3,83	-1,23	-3,12	>1380
9	71	4,29	-3,35	0,94	-2,18	1140
10	72	3,81	-3,70	0,11	-2,07	1195
11	73	4,67	-2,49	2,18	0,11	<870
12	74	3,57	-2,54	1,03	1,14	1065
13	75	4,64	-3,43	1,21	2,35	1050
14	76	4,40	-2,87	1,53	3,88	<870
15	77	2,33	-2,89	-0,56	3,32	1280
16	78	2,56	-3,07	-0,51	2,81	1290
17	79	3,28	-3,41	-0,13	2,68	1240
18	1980	2,51	-3,30	-0,79	1,89	1275
19	81	4,04	-3,82	0,22	2,11	1210
20	82	3,35	-3,48	-0,13	1,98	1240
21	83	4,79	-3,19	1,60	3,58	1010
22	84	4,09	-2,77	1,32	4,90	1050
23	85	2,44	-3,00	-0,56	4,34	1290
24	86	2,35	-2,76	-0,41	3,93	1255
25	87	4,29	-2,22	2,07	6,00	<870
26	88	2,73	-5,21	-2,48	3,52	>1380
27	89	5,20	-2,93	2,27	5,79	1030
28	1990	5,98	-4,19	1,79	7,58	995
29	91	4,09	-3,30	0,79	8,37	1035
30	92	5,48	-3,19	2,29	10,66	1050
31	93	4,81	-2,74	2,07	12,73	<870
32	94	3,71	-2,92	0,79	13,52	925
33	95	5,10	-3,90	1,20	14,72	1120
34	96	1,83	-3,71	-1,88	12,84	>1380
35	97	4,22	-4,14	0,08	12,92	1200
36	98	3,66	-3,55	0,11	13,03	1240
37	99	4,61	-4,55	0,06	13,09	1245
38	2000	5,57	-3,58	1,99	15,08	1025
39	01	1,86	-3,95	-2,09	12,99	>1382
40	02	3,78	-5,31	-1,53	11,46	>1382
Mean 1963-2002		3,74	-3,45	0,29		

2 Hansebreen - 3.1 km^2 (1997)

No. of	Year	bw	bs	bn	Cum. bn	ELA
years		(m w.eqv.)		(m w.eqv.)		(m a.s.l.)
1	1986	2,28	-2,87	-0,59	-0,59	1200
2	87	3,76	-2,63	1,13	0,54	1100
3	88	2,50	-5,24	-2,74	-2,20	>1320
4	89	4,13	-3,71	0,42	-1,78	1140
5	1990	4,42	-4,10	0,32	-1,46	1140
6	91	3,37	-3,11	0,26	-1,20	1125
7	92	4,41	-3,43	0,98	-0,22	1125
8	93	4,23	-3,15	1,08	0,86	<925
9	94	3,39	-2,97	0,42	1,28	1120
10	95	4,38	-3,90	0,48	1,76	1140
11	96	1,74	-3,76	-2,02	-0,26	>1320
12	97	3,77	-3,92	-0,15	-0,41	1160
13	98	3,21	-3,51	-0,30	-0,71	1170
14	99	4,30	-4,19	0,11	-0,60	1155
15	2000	4,69	-3,82	0,87	0,27	1075
16	01	1,71	-4,43	-2,72	-2,45	>1327
17	02	3,51	-5,44	-1,93	-4,38	>1327
Mean 1986-2002		3,52	-3,78	-0,26		

3 Blomsterskardsbreen - 45.7 km^2 (1959)

No. of	Year	bw	bs	bn	Cum. bn	ELA
years		(m w.eqv.)		(m w.eqv.)		(m a.s.l.)
1	1970					1370
2	71	2,85	-1,87	0,98	0,98	1240
3	72			0,32	1,30	1340
4	73			1,57	2,87	1180
5	74			0,51	3,38	1325
6	75			1,70	5,08	1170
7	76			1,40	6,48	1210
8	77			-1,40	5,08	>1640
Mean 1971-77				0,73		

4 Bondhusbrea - 10.7 km^2 (1979)

No. of	Year	bw	bs	bn	Cum. bn	ELA
years		(m w.eqv.)		(m w.eqv.)		(m a.s.l.)
1	77	1,96	-2,96	-1,00	-1,00	1620
2	78	2,37	-2,88	-0,51	-1,51	1540
3	79	2,82	-2,49	0,33	-1,18	1445
4	1980	2,33	-2,78	-0,45	-1,63	1500
5	81	3,32	-2,00	1,32	-0,31	1460
Mean 1977-81		2,56	-2,62	-0,06		

5 Breidablikkbrea - 3.6 km^2 (1997)

No. of	Year	bw	bs	bn	Cum. bn	ELA
years		(m w.eqv.)		(m w.eqv.)		(m a.s.l.)
1	1963	1,11	-2,32	-1,21	-1,21	1635
2	64	1,92	-1,68	0,24	-0,97	1450
3	65	1,72	-2,28	-0,56	-1,53	1525
4	66	1,52	-3,17	-1,65	-3,18	>1660
5	67	3,40	-2,23	1,17	-2,01	1355
6	68	3,55	-2,68	0,87	-1,14	1360
Mean 1963-68		2,20	-2,39	-0,19		

6 Gråfjellsbrea - 8.9 km^2 (1997)

No. of	Year	bw	bs	bn	Cum. bn	ELA
years		(m w.eqv.)		(m w.eqv.)		(m a.s.l.)
1	1964	1,94	-1,62	0,32	0,32	1385
2	65	2,01	-2,29	-0,28	0,04	1490
3	66	1,58	-2,93	-1,35	-1,31	>1660
4	67	3,46	-2,14	1,32	0,01	1355
5	68	3,39	-2,82	0,57	0,58	1380
6	1974	2,11	-1,53	0,58	0,58	1370
7	75	2,53	-2,28	0,25	0,83	1420
Mean 1964-68		2,48	-2,36	0,12		
Mean 1974-75		2,32	-1,91	0,42		

7 Blåbreen and Ruklebreen - 4.5 km^2 (1959)

No. of	Year	bw	bs	bn	Cum. bn	ELA
years		(m w.eqv.)		(m w.eqv.)		(m a.s.l.)
1	1963[1)]	1,30	-3,40	-2,10	-2,10	1620
2	64	2,18	-1,68	0,50	-1,60	1350
3	65	2,53	-2,48	0,05	-1,55	1450
4	66	1,76	-3,26	-1,50	-3,05	>1620
5	67	3,86	-2,56	1,30	-1,75	1300
6	68	3,18	-2,80	0,38	-1,37	1395
Mean 1963-68		2,47	-2,70	-0,23		

[1)] Blåbreen only

8 Midtre Folgefonna - 8.7 km^2 (1959)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1970	2,07	-2,69	-0,62	-0,62	>1580
2	71	2,33	-1,96	0,37	-0,25	1260
Mean 1970-71		2,20	-2,33	-0,13		

9 Jostefonn - 3.8 km^2 (1993)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1996	1,19	-2,72	-1,53	-1,53	>1620
2	97	3,59	-3,87	-0,28	-1,81	1500
3	98	2,84	-2,54	0,30	-1,51	1250
4	99	2,92	-2,54	0,38	-1,13	1200
5	2000	3,49	-2,47	1,02	-0,11	1050
Mean 1996-2000		2,81	-2,83	-0,02		

10 Vesledalsbreen - 4.2 km^2 (1966)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1967	2,06	-1,71	0,35	0,35	1400
2	68	3,14	-2,50	0,64	0,99	1320
3	69	1,26	-3,44	-2,18	-1,19	>1730
4	1970	1,52	-2,66	-1,14	-2,33	>1730
5	71	2,21	-1,80	0,41	-1,92	1375
6	72	1,92	-2,27	-0,35	-2,27	1570
Mean 1967-72		2,02	-2,40	-0,38		

11 Tunsbergdalsbreen - 50.1 km^2 (1964)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1966	1,57	-2,66	-1,09	-1,09	1640
2	67	3,31	-1,52	1,79	0,70	1160
3	68	2,74	-2,70	0,04	0,74	1550
4	69	1,53	-3,22	-1,69	-0,95	1700
5	1970	1,54	-2,38	-0,84	-1,79	1590
6	71	2,36	-1,79	0,57	-1,22	1240
7	72	2,02	-2,52	-0,50	-1,72	1490
Mean 1966-72		2,15	-2,40	-0,25		

12 Nigardsbreen - 47.8 km^2 (1984)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1962	2,88	-0,63	2,25	2,25	1260
2	63	1,87	-2,09	-0,22	2,03	1550
3	64	2,13	-1,18	0,95	2,98	1400
4	65	2,29	-1,38	0,91	3,89	1395
5	66	1,76	-2,68	-0,92	2,97	1700
6	67	3,40	-1,24	2,16	5,13	1310
7	68	2,72	-2,50	0,22	5,35	1550
8	69	1,95	-3,26	-1,31	4,04	1850
9	1970	1,73	-2,29	-0,56	3,48	1650
10	71	2,11	-1,29	0,82	4,30	1400
11	72	1,88	-2,02	-0,14	4,16	1570
12	73	2,40	-1,30	1,10	5,26	1410
13	74	2,06	-1,58	0,48	5,74	1490
14	75	2,50	-2,23	0,27	6,01	1450
15	76	2,88	-2,48	0,40	6,41	1540
16	77	1,52	-2,29	-0,77	5,64	1650
17	78	2,12	-2,25	-0,13	5,51	1590
18	79	2,75	-2,04	0,71	6,22	1500
19	1980	1,77	-2,99	-1,22	5,00	1730
20	81	2,19	-1,88	0,31	5,31	1560
21	82	1,94	-2,36	-0,42	4,89	1600
22	83	3,02	-1,93	1,09	5,98	1445
23	84	2,49	-2,15	0,34	6,32	1500
24	85	1,77	-1,87	-0,10	6,22	1590
25	86	1,61	-1,71	-0,10	6,12	1590
26	87	2,73	-1,25	1,48	7,60	1350
27	88	2,24	-3,13	-0,89	6,71	1660
28	89	4,05	-0,85	3,20	9,91	1175
29	1990	3,52	-1,75	1,77	11,68	1430
30	91	1,95	-1,75	0,20	11,88	1520
31	92	3,16	-1,56	1,60	13,48	1360
32	93	3,13	-1,28	1,85	15,33	1300
33	94	2,28	-1,72	0,56	15,89	1400
34	95	3,16	-1,97	1,19	17,08	1320
35	96	1,40	-1,81	-0,41	16,67	1660
36	97	2,66	-2,62	0,04	16,71	1500
37	98	2,50	-1,53	0,97	17,68	1350
38	99	2,38	-2,21	0,17	17,85	1470
39	2000	3,38	-1,66	1,72	19,57	1250
40	01	1,75	-1,97	-0,22	19,35	1560
41	02	2,41	-3,30	-0,89	18,46	1715
Mean 1962-2002		2,40	-1,95	0,45		

13 Store Supphellebreen - 12.0 km^2 (1966)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1964	2,20	-1,50	0,70	0,70	1190
2	65	2,32	-1,76	0,56	1,26	1250
3	66	1,63	-2,40	-0,77	0,49	1590
4	67	2,72	-1,50	1,22	1,71	1190
5	73			1,50	1,50	
6	74			0,80	2,30	
7	75			1,00	3,30	
8	79			1,10	1,10	
9	1980			-1,40	-0,30	
10	81			0,20	-0,10	
11	82			-1,70	-1,80	
Mean 1964-67		2,22	-1,79	0,43		
Mean 1973-75				1,10		
Mean 1979-82				-0,45		

14 Austdalsbreen - 11.8 km^2 (1988)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1988	1,94	-3,22	-1,28	-1,28	1570
2	89	3,18	-1,34	1,84	0,56	1275
3	1990	3,65	-2,45	1,20	1,76	1310
4	91	1,64	-1,64	0,00	1,76	1435
5	92	2,80	-2,26	0,54	2,30	1375
6	93	2,60	-1,69	0,91	3,21	1320
7	94	1,81	-1,88	-0,07	3,14	1425
8	95	2,72	-2,10	0,62	3,76	1360
9	96	1,20	-2,27	-1,07	2,69	1565
10	97	2,67	-3,20	-0,53	2,16	1450
11	98	2,20	-2,01	0,19	2,35	1420
12	99	2,08	-2,56	-0,48	1,87	1435
13	2000	2,77	-1,66	1,11	2,98	1315
14	01	1,04	-2,66	-1,62	1,36	>1757
15	02	1,91	-3,92	-2,01	-0,65	>1757
Mean 1988-2002		2,28	-2,32	-0,04		

15 Spørteggbreen - 27.9 km^2 (1988)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1988	1,61	-3,15	-1,54	-1,54	>1770
2	89	2,76	-1,62	1,14	-0,40	1410
3	1990	3,34	-2,33	1,01	0,61	1390
4	91	1,40	-1,37	0,03	0,64	1540
Mean 1988-91		2,28	-2,12	0,16		

16 Harbardsbreen - 13.2 km^2 (1996)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1997	2,17	-2,72	-0,55	-0,55	>1960
2	98	1,66	-1,60	0,06	-0,49	1500
3	99	1,81	-2,15	-0,34	-0,83	>1960
4	2000	2,30	-1,52	0,78	-0,05	1250
5	01	0,88	-1,99	-1,11	-1,16	>1960
Mean 1997-2001		1,76	-2,00	-0,23		

17 Rembesdalskåka - 17.1 km^2 (1995)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1963	1,15	-2,55	-1,40	-1,40	>1860
2	64	1,85	-1,31	0,54	-0,86	1620
3	65	2,05	-1,54	0,51	-0,35	1620
4	66	1,60	-2,24	-0,64	-0,99	1750
5	67	2,44	-1,25	1,19	0,20	1540
6	68	2,68	-2,15	0,53	0,73	1600
7	69	1,07	-2,97	-1,90	-1,17	>1860
8	1970	1,29	-1,89	-0,60	-1,77	1780
9	71	2,02	-1,28	0,74	-1,03	1600
10	72	1,78	-1,86	-0,08	-1,11	1650
11	73	2,62	-1,79	0,83	-0,28	1570
12	74	1,91	-1,50	0,41	0,13	1615
13	75	2,25	-2,10	0,15	0,28	1620
14	76	2,45	-2,30	0,15	0,43	1620
15	77	1,20	-1,92	-0,72	-0,29	>1860
16	78	1,80	-2,10	-0,30	-0,59	
17	79	2,40	-2,10	0,30	-0,29	
18	1980	1,45	-2,85	-1,40	-1,69	>1860
19	81	2,65	-1,80	0,85	-0,84	1590
20	82	1,40	-2,10	-0,70	-1,54	1800
21	83	3,75	-2,05	1,70	0,16	1450
22	84	2,05	-2,15	-0,10	0,06	1675
23	85	1,48	-2,00	-0,52	-0,46	1715
24	86	1,47	-1,57	-0,10	-0,56	1670
25	87	2,08	-1,14	0,94	0,38	1535
26	88	1,98	-3,13	-1,15	-0,77	1860
27	89	3,48	-1,37	2,11	1,34	1420
28	1990	3,65	-1,72	1,93	3,27	1450
29	91	1,52	-1,61	-0,09	3,18	1660
30	92	3,71	-1,72	1,99	5,17	1525
31	93	2,82	-0,91	1,91	7,08	1450
32	94	1,79	-1,63	0,16	7,24	1600
33	95	2,44	-2,14	0,30	7,54	1575
34	96	0,99	-2,10	-1,11	6,43	>1860
35	97	2,94	-3,41	-0,47	5,96	1700
36	98	2,47	-1,78	0,69	6,65	1585
37	99	2,04	-1,99	0,05	6,70	1685
38	2000	2,93	-1,50	1,43	8,13	1425
39	01	1,03	-1,88	-0,85	7,28	1760
40	02	2,39	-3,10	-0,71	6,57	1750
Mean 1963-2002		2,13	-1,96	0,16		

18 Omnsbreen - 1.5 km^2 (1969)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1966	1,44	-2,28	-0,84	-0,84	
2	67	2,21	-1,72	0,49	-0,35	
3	68	2,20	-2,38	-0,18	-0,53	1520
4	69	1,09	-3,68	-2,59	-3,12	
5	1970	1,12	-2,62	-1,50	-4,62	
Mean 1966-70		1,61	-2,54	-0,92		

19 Midtdalsbreen - 6.7 km^2 (1995)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	2000	2,89	-1,57	1,32	1,32	1500
2	01	1,26	-1,90	-0,64	0,68	1785
Mean 2000-2001		2,08	-1,74	0,34		

20 Tverråbreen - 5.9 km^2 ()

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1962	2,03	-1,28	0,75	0,75	
2	63	1,24	-2,46	-1,22	-0,47	
Mean 1962-63		1,64	-1,87	-0,24		

21 Blåbreen - 3.6 km^2 (1961)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1962	1,15	-0,35	0,80	0,80	<1550
2	63	0,85	-1,71	-0,86	-0,06	1970
Mean 1962-63		1,00	-1,03	-0,03		

22 Storbreen - 5.4 km^2 (1997)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	49	2,28	-2,08	0,20	0,20	1650
2	1950	1,52	-1,81	-0,29	-0,09	1750
3	51	1,13	-1,67	-0,54	-0,63	1770
4	52	1,44	-1,13	0,31	-0,32	1630
5	53	1,40	-2,25	-0,85	-1,17	1850
6	54	1,21	-1,98	-0,77	-1,94	1830
7	55	1,57	-2,06	-0,49	-2,43	1800
8	56	1,31	-1,48	-0,17	-2,60	1705
9	57	1,42	-1,37	0,05	-2,55	1680
10	58	1,54	-1,62	-0,08	-2,63	1700
11	59	1,07	-2,35	-1,28	-3,91	1930
12	1960	0,98	-2,07	-1,09	-5,00	1910
13	61	1,10	-1,62	-0,52	-5,52	1820
14	62	1,54	-0,82	0,72	-4,80	1510
15	63	0,96	-2,14	-1,18	-5,98	1900
16	64	1,16	-0,95	0,21	-5,77	1655
17	65	1,54	-1,2	0,34	-5,43	1650
18	66	1,25	-1,86	-0,61	-6,04	1815
19	67	1,89	-1,17	0,72	-5,32	1570
20	68	1,64	-1,59	0,05	-5,27	1700
21	69	1,22	-2,64	-1,42	-6,69	2020
22	1970	0,97	-1,69	-0,72	-7,41	1840
23	71	1,46	-1,28	0,18	-7,23	1690
24	72	1,39	-1,7	-0,31	-7,54	1770
25	73	1,48	-1,4	0,08	-7,46	1705
26	74	1,26	-1,02	0,24	-7,22	1630
27	75	1,55	-1,7	-0,15	-7,37	1760
28	76	1,81	-1,9	-0,09	-7,46	1740
29	77	0,94	-1,48	-0,54	-8,00	1840
30	78	1,26	-1,7	-0,44	-8,44	1815
31	79	1,55	-1,45	0,10	-8,34	1700
32	1980	0,99	-2,3	-1,31	-9,65	1975
33	81	1,30	-1,4	-0,10	-9,75	1730
34	82	1,28	-1,75	-0,47	-10,22	1780
35	83	1,90	-1,7	0,20	-10,02	1625
36	84	1,70	-2	-0,30	-10,32	1760
37	85	1,20	-1,6	-0,40	-10,72	1790
38	86	1,05	-1,37	-0,32	-11,04	1770
39	87	1,55	-1,23	0,32	-10,72	1580
40	88	1,45	-2,4	-0,95	-11,67	1970
41	89	2,30	-1,1	1,20	-10,47	1550
42	1990	2,60	-1,35	1,25	-9,22	1530
43	91	1,26	-1,41	-0,15	-9,37	1740
44	92	1,61	-1,53	0,08	-9,29	1715
45	93	1,81	-1,06	0,75	-8,54	1610
46	94	1,52	-1,77	-0,25	-8,79	1800
47	95	1,77	-1,93	-0,16	-8,95	1810
48	96	0,81	-1,84	-1,03	-9,98	1890
49	97	1,75	-2,78	-1,03	-11,01	1875
50	98	1,55	-1,33	0,22	-10,79	1690
51	99	1,67	-1,91	-0,24	-11,03	1850
52	2000	2,04	-1,49	0,55	-10,48	1650
53	01	1,05	-1,32	-0,27	-10,75	1855
54	02	1,09	-2,87	-1,78	-12,53	>2290
Mean 1949-2002		1,45	-1,68	-0,23		

23 Vestre Memurubre - 9.0 km^2 (1966)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1968	1,70	-1,46	0,24	0,24	1820
2	69	1,05	-2,11	-1,06	-0,82	2170
3	1970	0,84	-1,63	-0,79	-1,61	1990
4	71	1,30	-1,19	0,11	-1,50	1845
5	72	1,19	-1,47	-0,28	-1,78	1885
Mean 1968-72		1,22	-1,57	-0,36		

24 Austre Memurubre - 8.7 km^2 (1966)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1968	1,77	-1,76	0,01	0,01	1960
2	69	0,99	-2,45	-1,46	-1,45	2130
3	1970	0,81	-1,71	-0,90	-2,35	2090
4	71	1,33	-1,51	-0,18	-2,53	1960
5	72	1,02	-1,42	-0,40	-2,93	1985
Mean 1968-72		1,18	-1,77	-0,59		

25 Hellstugubreen - 3.0 km^2 (1997)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1962	1,18	-0,40	0,78	0,78	
2	63	0,94	-1,92	-0,98	-0,20	2020
3	64	0,71	-0,83	-0,12	-0,32	1900
4	65	1,29	-0,77	0,52	0,20	1690
5	66	0,95	-1,62	-0,67	-0,47	1940
6	67	1,48	-0,93	0,55	0,08	1800
7	68	1,38	-1,49	-0,11	-0,03	1875
8	69	0,95	-2,23	-1,28	-1,31	2130
9	1970	0,70	-1,70	-1,00	-2,31	2020
10	71	1,12	-1,25	-0,13	-2,44	1860
11	72	0,94	-1,43	-0,49	-2,93	1950
12	73	1,20	-1,41	-0,21	-3,14	1880
13	74	1,00	-0,76	0,24	-2,90	1785
14	75	1,35	-1,71	-0,36	-3,26	1950
15	76	1,16	-1,89	-0,73	-3,99	1970
16	77	0,68	-1,40	-0,72	-4,71	2075
17	78	1,05	-1,59	-0,54	-5,25	1890
18	79	1,43	-1,45	-0,02	-5,27	1820
19	1980	0,81	-2,05	-1,24	-6,51	2050
20	81	1,06	-1,39	-0,33	-6,84	1950
21	82	0,85	-1,20	-0,35	-7,19	1920
22	83	1,47	-1,30	0,17	-7,02	1820
23	84	1,22	-1,73	-0,51	-7,53	1965
24	85	1,11	-1,40	-0,29	-7,82	1880
25	86	0,78	-1,27	-0,49	-8,31	1940
26	87	1,15	-0,70	0,45	-7,86	1690
27	88	1,28	-2,32	-1,04	-8,90	2025
28	89	1,62	-0,90	0,72	-8,18	1660
29	1990	1,81	-1,15	0,66	-7,52	1640
30	91	0,98	-1,43	-0,45	-7,97	1950
31	92	1,17	-1,03	0,14	-7,83	1850
32	93	1,25	-0,95	0,30	-7,53	1670
33	94	1,26	-1,19	0,07	-7,46	1850
34	95	1,42	-1,54	-0,12	-7,58	1885
35	96	0,65	-1,39	-0,74	-8,32	1955
36	97	1,12	-2,77	-1,65	-9,97	2200
37	98	1,00	-1,02	-0,02	-9,99	1870
38	99	1,22	-1,64	-0,42	-10,41	1930
39	2000	1,26	-1,16	0,10	-10,31	1840
40	01	0,85	-1,21	-0,36	-10,67	1910
41	02	0,96	-2,37	-1,41	-12,08	2080
Mean 1962-2002		1,12	-1,41	-0,29		

26 Gråsubreen - 2.3 km^2 (1997)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1962	0,86	-0,09	0,77	0,77	1870
2	63	0,40	-1,11	-0,71	0,06	2275
3	64	0,39	-0,71	-0,32	-0,26	2160
4	65	0,77	-0,36	0,41	0,15	1900
5	66	0,72	-1,01	-0,29	-0,14	2150
6	67	1,45	-0,74	0,71	0,57	1870
7	68	1,03	-1,11	-0,08	0,49	2140
8	69	0,74	-2,04	-1,30	-0,81	2275
9	1970	0,57	-1,23	-0,66	-1,47	2200
10	71	0,49	-0,96	-0,47	-1,94	2200
11	72	0,66	-1,30	-0,64	-2,58	2240
12	73	0,72	-1,61	-0,89	-3,47	2275
13	74	0,58	-0,24	0,34	-3,13	1870
14	75	0,91	-1,86	-0,95	-4,08	2275
15	76	0,62	-1,62	-1,00	-5,08	2275
16	77	0,51	-0,90	-0,39	-5,47	2275
17	78	0,67	-0,89	-0,22	-5,69	2140
18	79	0,91	-0,87	0,04	-5,65	2025
19	1980	0,46	-1,35	-0,89	-6,54	2225
20	81	0,62	-0,81	-0,19	-6,73	2180
21	82	0,50	-1,01	-0,51	-7,24	2275
22	83	0,94	-0,99	-0,05	-7,29	2090
23	84	0,98	-1,35	-0,37	-7,66	2275
24	85	0,75	-0,75	0,00	-7,66	2100
25	86	0,42	-1,18	-0,76	-8,42	2275
26	87	0,94	-0,22	0,72	-7,70	1870
27	88	1,08	-1,66	-0,58	-8,28	2195
28	89	1,12	-0,67	0,45	-7,83	1870
29	1990	1,33	-0,60	0,73	-7,10	1870
30	91	0,67	-1,19	-0,52	-7,62	1950
31	92	0,70	-0,80	-0,10	-7,72	
32	93	0,93	-0,51	0,42	-7,30	<1850
33	94	1,16	-1,16	0,00	-7,30	2075
34	95	1,19	-1,30	-0,11	-7,41	2180
35	96	0,53	-0,98	-0,45	-7,86	2205
36	97	0,70	-2,39	-1,69	-9,55	>2290
37	98	0,78	-0,67	0,11	-9,44	undef.
38	99	0,91	-1,30	-0,39	-9,83	2210
39	2000	0,87	-0,92	-0,05	-9,88	undef.
40	01	0,80	-0,78	0,02	-9,86	2070
41	02	0,63	-2,05	-1,42	-11,28	>2290
Mean 1962-2002		0,78	-1,06	-0,28		

27 Charles Rabots Bre - 1.1 km^2 (1965)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1970			-1,90	-1,90	
2	71			0,47	-1,43	
3	72			-1,04	-2,47	
4	73			1,44	-1,03	
Mean 1970-73				-0,26		

28 Austre Okstindbre - 14.0 km^2 (1962)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1987	2,30	-1,60	0,70	0,70	1280
2	88	1,50	-3,40	-1,90	-1,20	>1750
3	89	3,70	-2,20	1,50	0,30	1275
4	1990	3,00	-2,70	0,30	0,60	1310
5	91	1,80	-2,30	-0,50	0,10	1315
6	92	2,88	-1,65	1,23	1,33	1260
7	93	2,22	-2,01	0,21	1,54	1290
8	94	1,45	-1,62	-0,17	1,37	1310
9	95	2,25	-1,79	0,46	1,83	1280
10	96	1,62	-1,92	-0,30	1,53	1330
Mean 1987-96		2,27	-2,12	0,15		

29 Høgtuvbreen - 2.6 km^2 (1972)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1971	3,05	-3,78	-0,73	-0,73	950
2	72	3,34	-4,30	-0,96	-1,69	970
3	73	3,90	-2,82	1,08	-0,61	720
4	74	3,46	-3,68	-0,22	-0,83	900
5	75	3,00	-2,27	0,73	-0,10	760
6	76	3,66	-2,75	0,91	0,81	730
7	77	2,20	-2,72	-0,52	0,29	900
Mean 1971-77		3,23	-3,19	0,04		

30 Svartisheibreen - 5.5 km^2 (1985)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1988	2,42	-4,03	-1,61	-1,61	1180
2	89	3,72	-1,36	2,36	0,75	900
3	1990	3,79	-2,97	0,82	1,57	930
4	91	2,61	-2,44	0,17	1,74	950
5	92	3,89	-2,68	1,21	2,95	890
6	93	3,50	-2,59	0,91	3,86	910
7	94	1,83	-1,85	-0,02	3,84	975
Mean 1988-94		3,11	-2,56	0,55		

31 Engabreen - 38.0 km^2 (1968)

No. of years	Year	bw (m w.eqv.)	bs	bn (m w.eqv.)	Cum. bn	ELA (m a.s.l.)
1	1970	2,05	-3,04	-0,99	-0,99	1280
2	71	3,20	-2,19	1,01	0,02	1070
3	72	3,22	-3,29	-0,07	-0,05	1150
4	73	4,37	-1,65	2,72	2,67	830
5	74	3,39	-2,59	0,80	3,47	1030
6	75	3,18	-1,57	1,61	5,08	960
7	76	3,86	-1,45	2,41	7,49	910
8	77	2,08	-1,20	0,88	8,37	1000
9	78	2,48	-2,99	-0,51	7,86	1250
10	79	3,64	-3,22	0,42	8,28	1130
11	1980	2,68	-3,18	-0,50	7,78	1270
12	81	2,91	-1,93	0,98	8,76	965
13	82	2,27	-1,43	0,84	9,60	1030
14	83	2,34	-1,28	1,06	10,66	1020
15	84	3,83	-2,78	1,05	11,71	1000
16	85	1,50	-2,40	-0,90	10,81	1375
17	86	2,70	-2,45	0,25	11,06	1170
18	87	2,57	-1,63	0,94	12,00	1000
19	88	2,26	-4,05	-1,79	10,21	1400
20	89	4,62	-1,45	3,17	13,38	890
21	1990	3,49	-2,64	0,85	14,23	1035
22	91	2,83	-2,14	0,69	14,92	1090
23	92	4,05	-1,71	2,34	17,26	875
24	93	3,06	-2,02	1,04	18,30	985
25	94	1,95	-1,53	0,42	18,72	1050
26	95	3,50	-1,76	1,74	20,46	940
27	96	2,97	-2,14	0,83	21,29	970
28	97	4,44	-3,22	1,22	22,51	1010
29	98	2,98	-2,77	0,21	22,72	1100
30	99	2,12	-2,15	-0,03	22,69	1215
31	2000	2,76	-1,27	1,49	24,18	970
32	01	1,05	-2,58	-1,53	22,65	>1594
33	02	2,89	-3,48	-0,59	22,06	1200
Mean 1970-2002		2,95	-2,28	0,67		

32 Storglombreen - 62.4 km^2 (1968)

No. of	Year	bw	bs	bn	Cum. bn	ELA
years		(m w.eqv.)		(m w.eqv.)		(m a.s.l.)
1	1985	1,40	-2,59	-1,19	-1,19	1300
2	86	2,45	-2,87	-0,42	-1,61	1100
3	87	2,32	-1,87	0,45	-1,16	1020
4	88	2,06	-3,88	-1,82	-2,98	1350
5	2000	2,66	-1,55	1,11	1,11	1000
6	01	1,15	-2,91	-1,76	-0,65	>1580
7	02	2,35	-3,60	-1,25	-1,90	>1580
Mean 1985-88		2,06	-2,80	-0,75		
Mean 2000-02		2,05	-2,69	-0,63		

33 Tretten-null-tobreen - 4.9 km^2 (1968)

No. of	Year	bw	bs	bn	Cum. bn	ELA
years		(m w.eqv.)		(m w.eqv.)		(m a.s.l.)
1	1985	1,47	-3,20	-1,73	-1,73	>1260
2	86	2,40	-2,84	-0,44	-2,17	1100
Mean 1985-86		1,94	-3,02	-1,09		

34 Glombreen - 2.2 km^2 (1953)

No. of	Year	bw	bs	bn	Cum. bn	ELA
years		(m w.eqv.)		(m w.eqv.)		(m a.s.l.)
1	1954	2,30	-3,50	-1,20	-1,20	
2	55	2,60	-2,70	-0,10	-1,30	
3	56	1,50	-2,10	-0,60	-1,90	
Mean 1954-56		2,13	-2,77	-0,63		

35 Kjølbreen - 3.9 km^2 (1953)

No. of	Year	bw	bs	bn	Cum. bn	ELA
years		(m w.eqv.)		(m w.eqv.)		(m a.s.l.)
1	1954	1,90	-2,60	-0,70	-0,70	
2	55	2,10	-2,80	-0,70	-1,40	
3	56	1,10	-1,10	0,00	-1,40	
Mean 1954-56		1,70	-2,17	-0,47		

36 Trollbergdalsbreen - 1.6 km^2 (1985)

No. of	Year	bw	bs	bn	Cum. bn	ELA
years		(m w.eqv.)		(m w.eqv.)		(m a.s.l.)
1	1970	1,74	-4,21	-2,47	-2,47	>1370
2	71	2,14	-2,47	-0,33	-2,80	1100
3	72	2,44	-3,68	-1,24	-4,04	1160
4	73	3,19	-2,43	0,76	-3,28	<900
5	74	2,57	-2,97	-0,40	-3,68	1090
6	75			-0,28	-3,96	1090
7	1990	2,94	-3,23	-0,29	-0,29	1075
8	91	2,29	-2,45	-0,16	-0,45	1070
9	92	2,63	-2,13	0,50	0,05	<900
10	93	2,45	-2,38	0,07	0,12	1045
11	94	1,49	-2,59	-1,10	-0,98	1180
Mean 1970-74(75)		2,42	-3,15	-0,66		
Mean 1990-94		2,36	-2,56	-0,20		

37 Rundvassbreen - 11.6 km^2 (1998)

No. of	Year	bw	bs	bn	Cum. bn	ELA
years		(m w.eqv.)		(m w.eqv.)		(m a.s.l.)
1	2002	2,14	-3,19	-1,05		1320

38 Blåisen - 2.2 km^2 (1960)

No. of	Year	bw	bs	bn	Cum. bn	ELA
years		(m w.eqv.)		(m w.eqv.)		(m a.s.l.)
1	1963	2,60	-2,40	0,20	0,20	1050
2	64	2,30	-1,67	0,63	0,83	980
3	65	2,00	-1,46	0,54	1,37	960
4	66	1,12	-2,39	-1,27	0,10	>1200
5	67	1,38	-2,35	-0,97	-0,87	1175
6	68	1,62	-1,36	0,26	-0,61	1010
Mean 1963-68		1,84	-1,94	-0,10		

39 Storsteinsfjellbreen - 5.9 km^2 (1993)

No. of	Year	bw	bs	bn	Cum. bn	ELA
years		(m w.eqv.)		(m w.eqv.)		(m a.s.l.)
1	1964	1,85	-1,20	0,65	0,65	1220
2	65	1,69	-1,25	0,44	1,09	1270
3	66	1,05	-1,88	-0,83	0,26	1500
4	67	1,37	-1,77	-0,40	-0,14	1450
5	68	1,44	-0,99	0,45	0,31	1275
6	1991	1,59	-1,63	-0,04	-0,04	1395
7	92	2,21	-1,10	1,11	1,07	1250
8	93	2,10	-1,29	0,81	1,88	1260
9	94	1,15	-1,35	-0,20	1,68	1375
10	95	1,81	-1,24	0,57	2,25	1280
Mean 1964-68		1,48	-1,42	0,06		
Mean 1991-95		1,77	-1,32	0,45		

40 Cainhavarre - 0.7 km^2 (1960)

No. of	Year	bw	bs	bn	Cum. bn	ELA
years		(m w.eqv.)		(m w.eqv.)		(m a.s.l.)
1	1965	1,41	-1,20	0,21	0,21	1300
2	66	1,12	-2,07	-0,95	-0,74	>1550
3	67	1,63	-1,79	-0,16	-0,90	1450
4	68	1,31	-1,05	0,26	-0,64	1290
Mean 1965-68		1,37	-1,53	-0,16		

41 Svartfjelljøkelen - 2.7 km^2 (1966)

No. of	Year	bw	bs	bn	Cum. bn	ELA
years		(m w.eqv.)		(m w.eqv.)		(m a.s.l.)
1	1978	2,30	-2,40	-0,10	-0,10	
2	79	2,10				
Mean 1978-79		2,20				

42 Langfjordjøkelen - 3.7 km^2 (1994)

No. of	Year	bw	bs	bn	Cum. bn	ELA
years		(m w.eqv.)		(m w.eqv.)		(m a.s.l.)
1	89	2,40	-2,96	-0,56	-0,56	870
2	1990	2,74	-3,06	-0,32	-0,88	780
3	91	2,31	-2,31	0,00	-0,88	710
4	92	2,68	-2,49	0,19	-0,69	700
5	93	2,55	-2,35	0,20	-0,49	740
6	96	2,25	-2,23	0,02	0,02	700
7	97	2,65	-3,34	-0,69	-0,67	820
8	98	1,80	-3,24	-1,44	-2,11	>1050
9	99	1,33	-2,91	-1,58	-3,69	970
10	2000	2,51	-3,12	-0,61	-4,30	860
11	01	1,36	-3,64	-2,28	-6,58	>1050
12	02	2,19	-3,73	-1,54	-8,12	>1050
Mean 1989-93		2,54	-2,63	-0,10		
Mean 1996-2002		2,01	-3,17	-1,16		