POLISH POLAR RESEARCH	21	1	3–18	2000

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Ablation and discharge of the Waldemar Glacier, north-western Spitsbergen in summer 1998

ABSTRACT: In summer 1998 detailed measurements of ablation were carried out on the Waldemar Glacier in order to determine its spatial and time variation. Five-days' average ablation was equal to 14.7 cm water equivalent (w.e.), with maximum total ablation of 160–180 cm w.e. at 200 m a.s.l., and the lowest ablation of 106 cm w.e. at 350 m a.s.l. Total ablation for the whole glacier was estimated at 120.5 cm w.e. Simplified scheme of changes of summer ablation with altitude was exampled by this glacier. Relation between discharge from individual fragments of the Waldemar Glacier and their ablation was examined. Discharge of the Waldemar River was analysed: from about 4,800,000 m^3 of water in the stream, 67% came from surface ablation of the Waldemar Glacier.

Key words: Arctica, Spitsbergen, Waldemar Glacier, summer ablation, outflow.

Introduction

Ablation and snow accumulation are the basic processes that influence balance of a glacier. Their relation allows estimation of changes in a glacier i.e. mass balance of its body. Ablation is more or less responsible for ice mass decrement. This process is a main glaciological problem, which has been dealt with by many authors (Sugden and John 1976; John 1977; Jania 1993, 1994; Jania and Hagen 1996; Dowdeswell *et al.* 1997). Ablation is more and more often considered in mathematical and statistical formula, aiming to forecasting its occurrence in time (Konovalov 1987, Krenke and Menshutin 1987, Pelto 1988, Hagen *et al.* 1993, Vincent and Vallon 1997). Many of the issues connected with the problem have not been, however, well recognised so far.

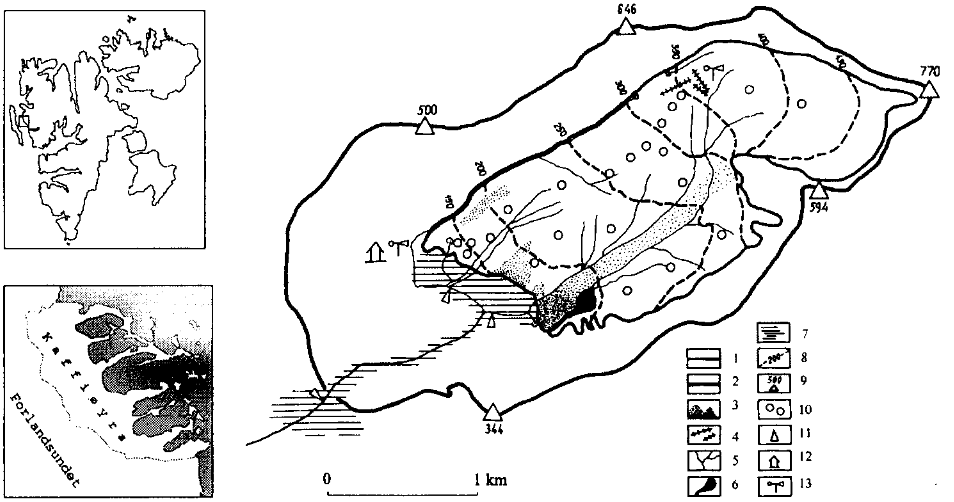

Fig. 1. Map of the Waldemar Glacier. 1 – glacier border, 2 – border of glacier drainage basin, 3 – median and surface moraine, 4 – gaps, 5 – supraglacial and proglacial streams, 6 – lake, 7 – icing, 8 – contour line, 9 – altitude point, 10 – ablation stakes, 11 – gauge station, 12 – glaciological observatory, 13 – meteorological station.

Studies of ablation should focus not only on a glacier surface but also on analysis of water conditions in a glacier catchment basin. Simultaneous measurements on surface and forefield of a glacier essentially increase accuracy of research (Sobota 1998).

In summer 1998 detailed measurements of ablation on the Waldemar Glacier were carried out in order to define its spatial and time variation (Fig. 1). Water discharge was measured in streams that drained individual parts of a glacier. Thus, it was possible to compare ablation of a glacier fragment with volume of outflowing water. Investigations included also the Waldemar River, which flows out from the glacier. The research focused mainly on correlation between intensity of water discharge and glacial ablation. An attempt to estimate ablation and outflow was done on the basis of temperature measurements in the Waldemar River. In order to carry out such research (which is a part of a program on ice mass balance of the Waldemar Glacier), the automatic gauging station "Davis" was used for the first time. It enabled to measure temperatures every 15 minutes.

Ablation of glaciers in Spitsbergen was discussed in numerous papers (Baranowski 1977; Leszkiewicz 1982, 1987; Haeberli, Hoelze and Bosch 1991, 1994, 1996; Jania 1993, 1994; Jania and Hagen 1996; Bartoszewski 1998). In spite of many expeditions to Kaffiøyra since 1975, glaciological research has concerned rarely ablation of glaciers in this area. Since 1995 systematic research has been a part of ice mass balance estimation of the Waldemar Glacier (Grześ 1997; Grześ and Sobota 1997, 1998; Sobota 1997). However, water conditions in Kaffiøyra have been widely discussed in literature, among others by Szczepanik (1977), Pietrucień (1977), Marszelewski (1987), Pietrucień, Skowron and Lankauf (1987), Skowron (1995), Sobota (1997, 1998) and Brykała (*unpubl.*).

Study area

The Waldemar Glacier is located in the northern Oscar II Land, northwestern Spitsbergen (Fig. 1). It is the alpine glacier and flows down a valley to the Kaffiøyra Plain. With the area of 2.66 km^2, the Waldemar Glacier occupies 61% of a catchment basin, closed by ice-cored moraines at the water gap. The firn field occurs at 380–490 m a.s.l. and the snout at 130 m a.s.l. The glacier is composed of two parts, separated by a median moraine, 1600 m long (Fig. 1). Its foreland occupies 0.44 km^2. A small ice-dam lake has been observed on the glacier since 1995, tightly related to the glacier retreat, resulting in ice melting and outflow blocking. The catchment basin of the Waldemar River occupies 16.5 km^2 and its surface has been shaped mainly by meltwaters from the Waldemar Glacier. Within the catchment basin there are streams fed by ablation, rainfall and melting of the morainal ice-cores. A river mouth is influenced by sea tides.

Location of the glacier snout is also significant for regime of the glacial stream. The Waldemar Glacier has been retreating intensively lately and the glacier surface lowered 1% every year (Lankauf and Preisner 1982; Lankauf 1989, 1993, 1995). This process undoubtedly influences considerably the outflow from the catchment basin of the Waldemar Glacier.

Ablation of the Waldemar Glacier

Similarly as in previous years, measurements of summer ablation in 1998 were carried out in 5 days' intervals at 30 sites on the glacier (Fig. 1). Aluminium poles were installed at depth 1.5 m in April and May 1998. In result, total surface ablation could be estimated for the whole summer. Investigations aimed to determine ablation in time and its variation with altitude, as well as to estimate average ablation in summer. Finally, ablation could be compared with runoff from a given part of the glacier.

Many agents, both morphological (morainal cover, slope, density of supraglacial streams, shielding) and meteorological (mainly air temperature) influence the ablation. High cloudiness occurred in summer 1998. As far as average air temperatures are concerned, they were also high and equal to 5°C on surface of the Waldemar Glacier, 5.7°C at the snout and 4.2°C at the firn field (according to measurements at the automatic meteorological gauging station "Davis"). Meteorological measurements enabled evaluation of tangible relation between air temperature

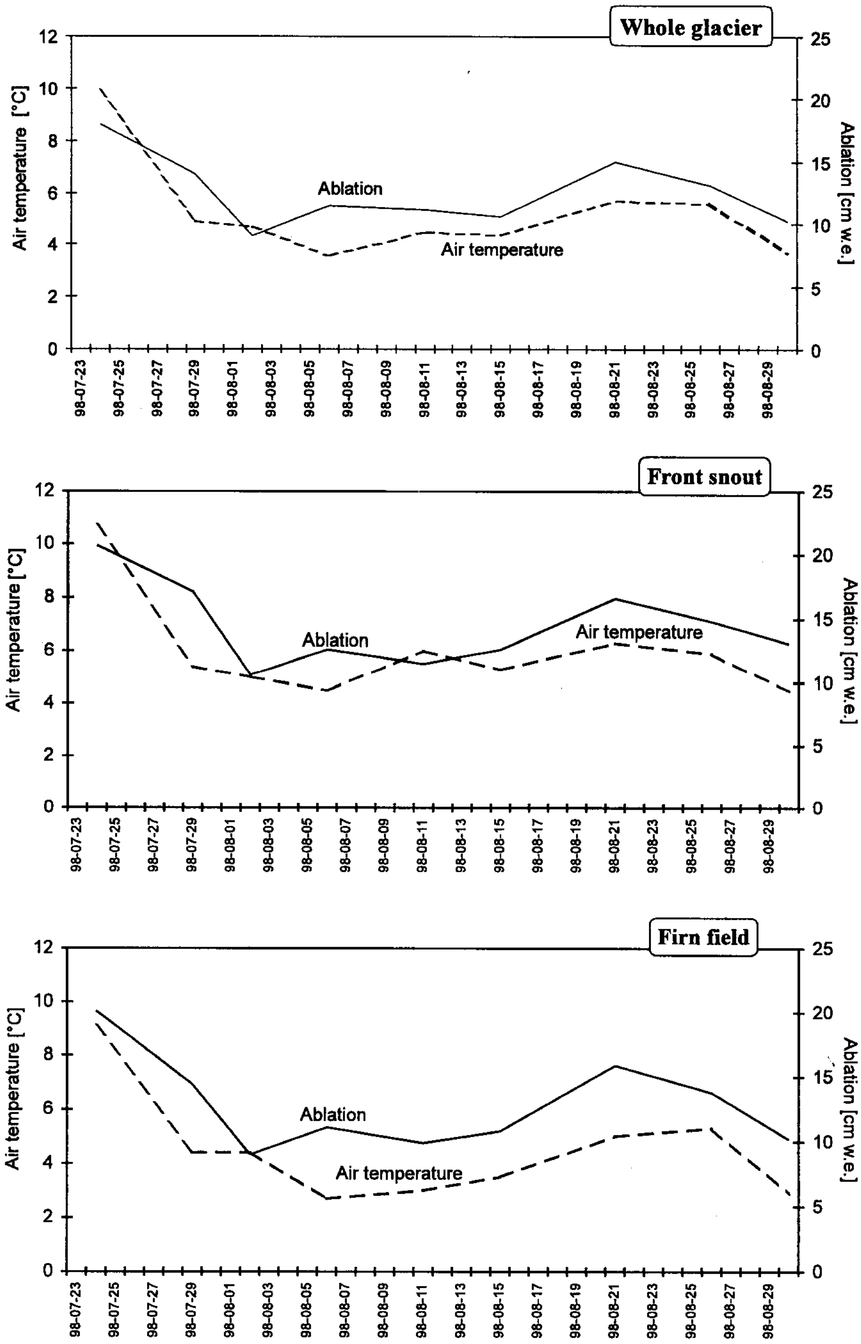

Fig. 2. Penta-ablation in individual parts of the Waldemar Glacier related to average air temperature in summer 1998.

Table 1
Ablation (in cm of water equivalent) at different altitudes on the Waldemar Glacier in summer 1996, 1997 and 1998.

Altitude [m a.s.l.]	1996		1997		1998	
	Ablation	Difference in ablation	Ablation	Difference in ablation	Ablation	Difference in ablation
150	93, 94, 120, 132	39	97, 126, 133	36	153, 159	6
200	60, 75	15	91, 109	18	108, 166	58
220	–	–	75, 83	8	130, 182	52
250	51, 64	13	51, 81	30	118, 140	22
300	48, 59, 61	13	46, 51	5	–	–
350	30, 41	11	53	–	109, 118	9
400	–	–	19, 24	5	125	–
450	–	–	–	–	131	–

and ablation (Fig. 2). Regardless the glacier part, ablation increases distinctly with rising temperature. Air temperature, often modified by local conditions on a glacier, is the most important factor for the ablation.

High intensity of ablation and lack of this phenomenon are observed on the Waldemar Glacier irrespectively of altitude. Unlike the previous summers, ablation was relatively constant. The highest ablation was noted at the beginning of the analysed period. Afterwards, decreasing ablation followed by its slight increase at the end of the examined period was observed. The lowest ablation, both at the snout and in the firn field, was ascertained between 29th July and 2nd August 1998 (10.6 cm w.e. and 9.0 cm w.e., accordingly). The highest ablation in these parts of the glacier was noted at the beginning of the analysed season (20.7 and 20.1 cm w.e.). The five-days' average ablation for the entire glacier was equal to 14.7 cm w.e. Contrary to the previous summers, ablation started nearly at the same time on the whole glacier and lasted for nearly the same period. It results from similar trend in temperature variation at individual parts of the glacier.

Ablation is dependent also on the so-called ablation layer. Ice melting occurs on ice crystals too, and white colour of glacier surface is due to this process. In summer 1998 the ice layer was to 20 cm thick. It disappeared completely during rain and its thickness was generally considerably varying. Real surface of ablation occurs only in case of absence of ablation. Both the Waldemar Glacier and altitude difference between the firn field and the snout (365 m) are relatively small. Nevertheless, spatial variation of ablation is observed. Besides the altitude gradient, variation was caused by local conditions including exposition, selective melting, slope and pattern of supraglacial streams.

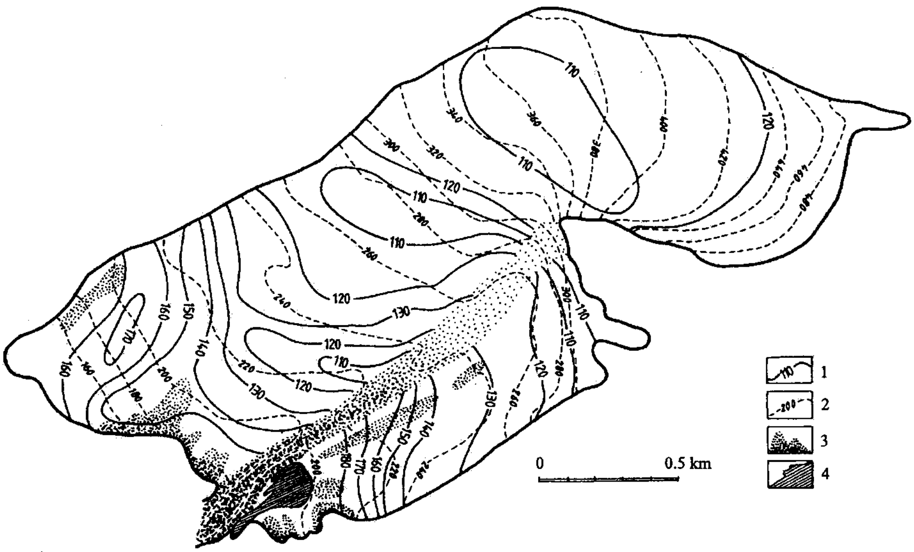

Fig. 3. Ablation map of the Waldemar Glacier in 1998. 1 – ablation (water equivalent in cm), 2 – contour line, 3 – median and surface moraine, 4 – lake.

The map of ablation of the Waldemar Glacier presents decreasing ablation with increasing altitude (Fig. 3). The highest ablation was noted at the glacier snout up to 250 m a.s.l.. The maximum total ablation was equal to 160–180 cm w.e. at 200 m a.s.l., whereas the lowest one to 106 cm w.e. at 350 m a.s.l. The gradient of ablation for the whole research period was only 10 cm w.e. at 100 m a.s.l., it was 22 cm w.e. at the same altitude in summer 1997. The lowest total ablation was not noted at the highest point of the firn field but a bit lower (Fig. 4). Ablation on the firn field was observed from the beginning of the ablation season. This process was so intensive that dense network of supraglacial channels developed together with a few ice crevasses, influencing a considerably varied ablation. Distribution and variability of glacial zones, characteristic for the previous seasons, could not be observed. Throughout the whole summer, the glacier occurred within the ablation zone. Additionally, small patches of water-ice pulp were formed but disappeared very quickly.

In summer 1998 the altitude did not influence much a spatial variation of ablation. Local conditions, mainly air temperature and foehn winds played much greater role, especially in the glacier firn field. This conclusion is based on total ablation in the firn field, equal to 122 cm w.e., and was higher than the average total ablation for the whole glacier (120.5 cm w.e.). The correlation coefficient between altitude and ablation during the analysed period was equal to 0.53 only, whereas it was 0.93 during the previous summer. It confirms much lower spatial variation of ablation.

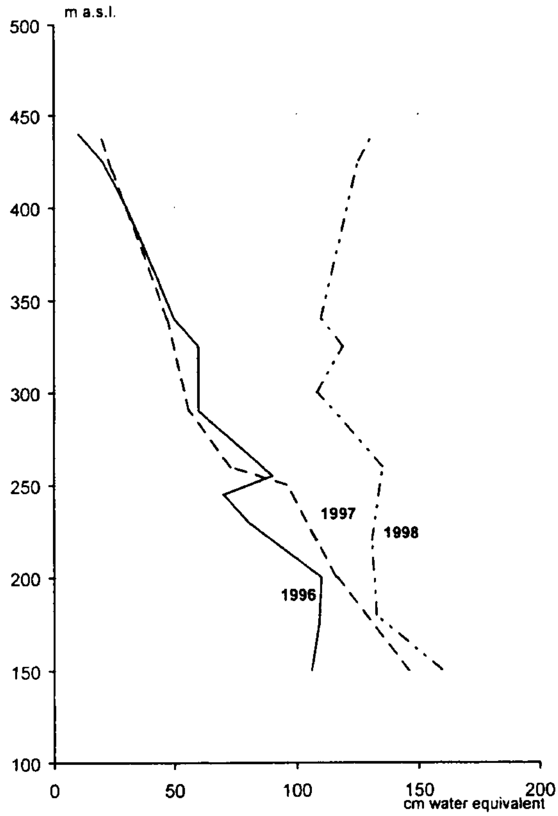

Fig. 4. Vertical variation of ablation on the Waldemar Glacier in summers 1996–1998.

Varying ablation with the altitude, dissimilar to the previous seasons, was a reason for detailed analysis of the Waldemar Glacier. It seems characteristic that ablation indicates strong diversity at the same altitude (Table 1). Sometimes these differences are significant as *e.g.* in summer 1998 when ablation was equal to 58 cm w.e. at 200 m a.s.l. In accordance with a general trend towards ablation getting lower with altitude, the ablation diversity increases. This situation is tightly connected with local conditions on the Waldemar Glacier. Its lower part, showing the most intensive ablation, stretches up to about 300 m a.s.l. It is generally covered with surface moraine. The fact that at different altitudes similar features exist makes altitude gradient insignificant for ablation. Participation of different fragments of the glacier in total ablation gives similar results to the quoted above. The whole central part of the Waldemar Glacier, irrespectively of its altitude, is subjected to similar ablation. These observations, however, do not exclude general decrease of ablation with altitude.

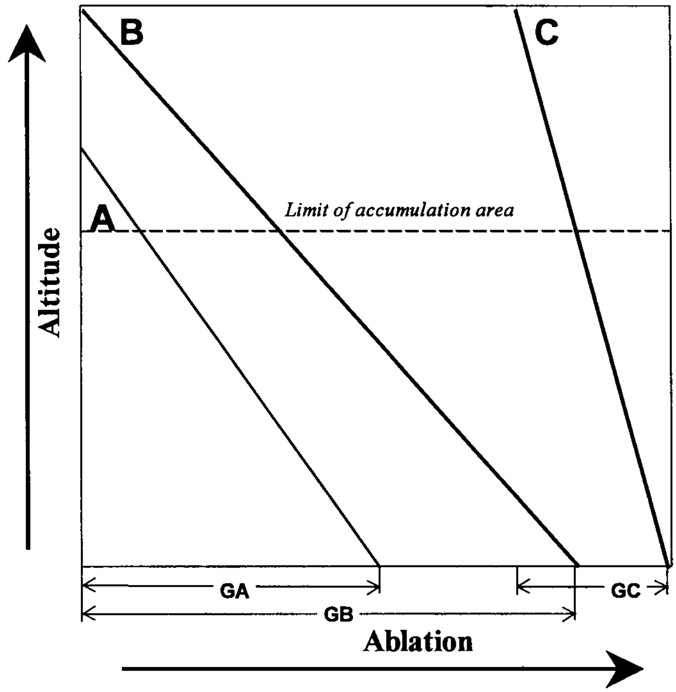

Fig. 5. Simplifed scheme of summer ablation against altitude. Type of summer: A – cold, B – average, C – warm; ablation gradients during: GB – average, GA – cold, and GC – warm summer; more comments in text.

The estimated ablation for the Waldemar Glacier resulted in a simplified scheme of glacier ablation variability with altitude (Fig. 5). Weather conditions and particularly air temperature during summer were accepted as the most important factor for ablation distribution. Meteorological factors were treated together. Summers were divided into three types including cold summer with average temperature lower than a multi-annual average one, average summer with average temperature similar to a multi-annual one, and warm summer with average temperature higher than a multi-annual one.

The second examined factor included local glacier conditions that more or less influenced variability of ablation with altitude. Snow accumulation in winter does not play any significant role and ablation is more or less intensive, depending on meteorological conditions in summer. Ablation drops with air temperature decreasing with altitude. Thus, air temperature is so low during a cold summer that from certain altitude melting does not occur on a glacier surface. The presented scheme shows three variants of altitudinal distribution of ablation (Fig. 5). During a cold summer ablation decreases distinctly up to certain altitude (in most cases to a firn field), above which it does not take place at all. The ablation gradient is quite high, but not the highest one. During an average summer ablation decreases considerably with

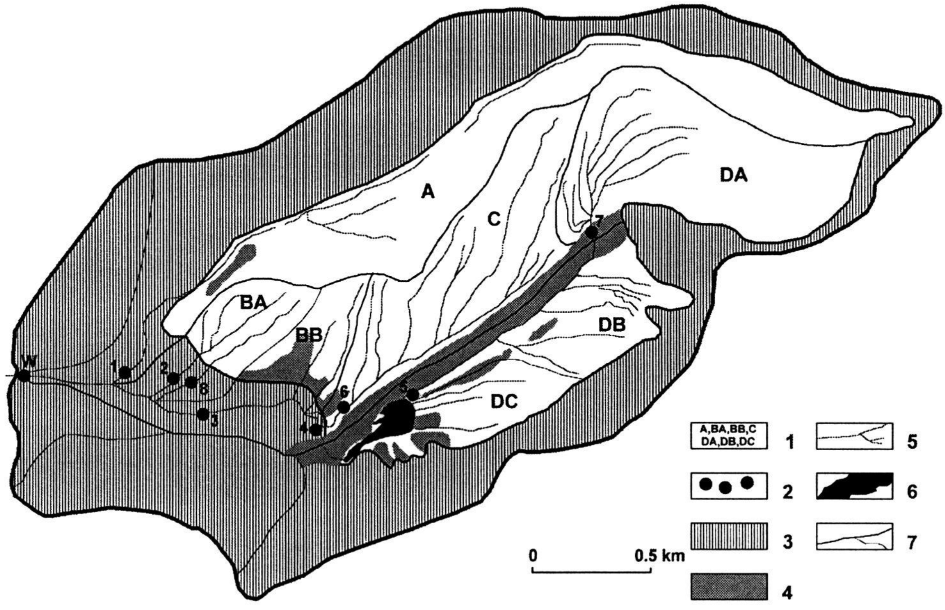

Fig. 6. Balance areas on the Waldemar Glacier in summer 1998. 1 – glacier areas drained by individual streams, 2 – outflow measurements points, 3 – ice-free area, 4 – surface and median moraines, 5 – supraglacial streams, 6 – ice-dam lake, 7 – limits of balance areas.

altitude, its values are big and the gradient is the biggest. Warm summer is characterised by most intensive ablation, taking place on the whole glacier but its variability is smaller with increasing altitude and the ablation gradient is the lowest one. Thus, as far as other glaciers similar to the Waldemar Glacier are concerned, various courses of ablation changing with altitude are expected in accordance with thermal conditions in summer. Such variability can be expressed by the ablation gradients GB > GA > GC, where GB is typical for average, GA – cold, and GC – warm summer.

The scheme presented above is modified slightly if completed with local conditions on a glacier. The lines for individual summers (A, B and C) are similarly inclined. Additionally, relations of their ablation gradients do not change, but their values are lower. Up to certain altitude, ablation does not change and its values are similar. The zone of similar ablation stretches up highest during a warm summer while lowest during a cold one. The presented scheme was based on detailed measurements of ablation on the Waldemar Glacier. Small size of the glacier plays significant role, as the whole glacier is located in similar weather conditions. The other glaciers in Spitsbergen, size and altitude of which are similar to those of the Waldemar Glacier, present similar distribution of ablation with altitude.

During the whole period of examination (last measurements taken on August 31) ablation of the Waldemar Glacier was equal to 120.5 cm w.e., and was much

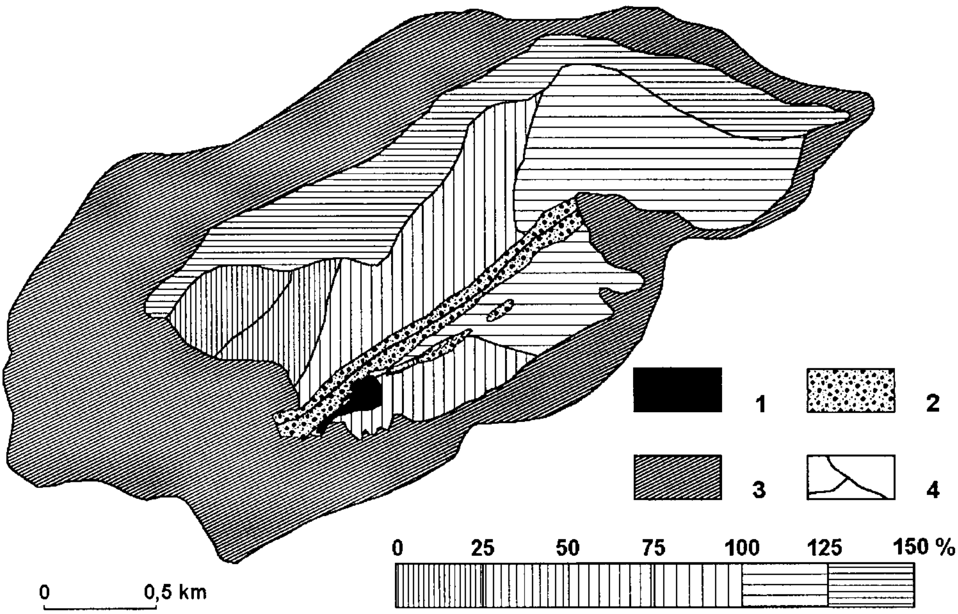

Fig. 7. Participation of surface runoff against ablation in total discharge from particular areas of the Waldemar Glacier in summer 1998. 1 – ice-dam lake, 2 – median and surface moraine, 3 – ice-free area, 4 – limits of drainage areas.

higher than during the two previous summers. Variation of ablation was also lower with time. The cumulated ablation of the Waldemar Glacier during the last three years was about 280 cm w.e., half of which occurred during the analysed season.

Outflow from the Waldemar Glacier

Supraglacial streams are the main morphological elements on a glacier surface in summer, especially in a frontal part. Intensified ablation creates or renews network of meltwater streams. Pattern of streams, their number, depth and time variation reflect the ablation rate. This paper focuses predominantly on volume of water transported in selected streams on the Waldemar Glacier and their relation to the outflow from individual parts of a glacier. The ablation based on the runoff hydrogram was estimated due to analysis of discharge from individual fragments of the catchment basin. Such approach enables determination of relation between ablation and partial outflow. This issue is very complicated and it allows only for rough comparison of the above parameters. Discharge from a given part of a glacier may indicate the ablation rate as well as its share in feeding the supraglacial streams with meltwater (Sobota 1998). Moreover, knowledge of partial outflow of streams directly at water outbursts from a glacier allows estimating share of sur-

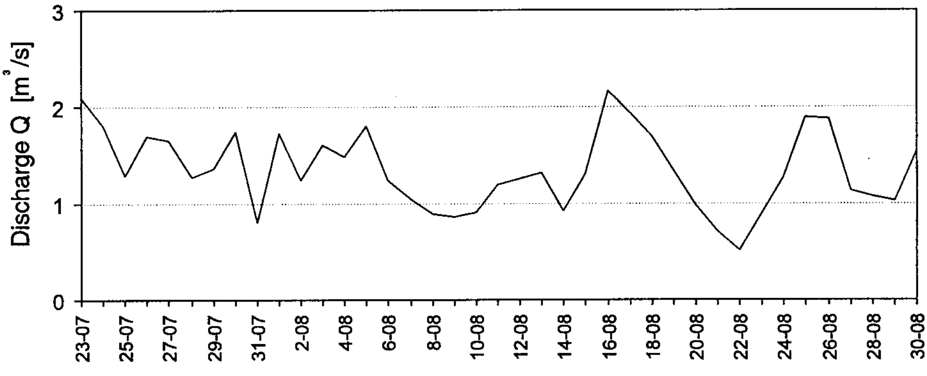

Fig. 8. Discharge of the Waldemar River in summer 1998.

face ablation in total outflow from a drainage area. It also enables to assess share of melting icings, which seems to be quite large. Precise estimation of volume of englacial water seems also possible.

In order to estimate outflow of streams the glacier was divided into characteristic balance areas (Fig. 6), limits of which follow roughly the watersheds on the glacier. Not only ablation for each fragment of the glacier was assessed within a research period but also outflow of streams draining those areas. Distinct relation between time variation of ablation in the defined areas and outflow rate of streams draining those areas was ascertained. This relation, however, was ambiguous. In some areas ablation was higher than outflow (Fig. 7) but opposite relation occurred occasionally too. For instance, share of ablation in outflow from the area BA was equal to 19% only while in the area A – as much as 134%. Similar analysis was carried out for the previous season (Sobota 1998). All these differences are tightly correlated with local conditions of individual catchment basins and have their justification. The above relation can create the basis for estimating the outflow from the glacier as well as the englacial outflow. This issue, however, is very complicated.

In summer 1998 standard measurements of discharge in the Waldemar River were taken, and relation of river outflow to glacial ablation was determined. Additionally, several physico-chemical properties of river water were examined. The investigations also included the ice-dam lake, outflow from which plays significant role in total outflow from the Waldemar Glacier and in feeding the analysed river. The "Davis" measuring equipment enabled very detailed water temperature measurements that were taken for the first time and every quarter of an hour. Such frequency allowed drawing conclusions on relation between river water and air temperature, and ablation.

Considerable time variation in discharge, especially up-stream, is characteristic for glacial rivers and the same is typical for the Waldemar River (Fig. 8). There were several alternate periods with high and low discharge. The course was tightly

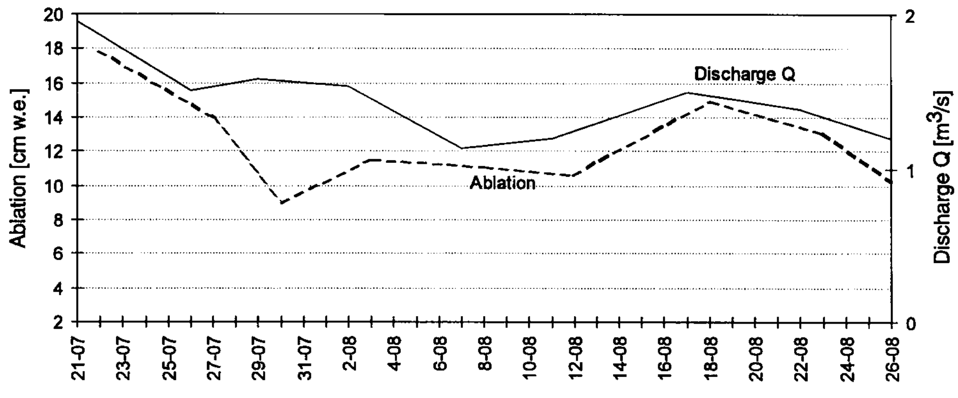

Fig. 9. Variability of average penta-flow intensity in the upper part of the Waldemar River, based on ablation of the Waldemar Glacier in summer 1998.

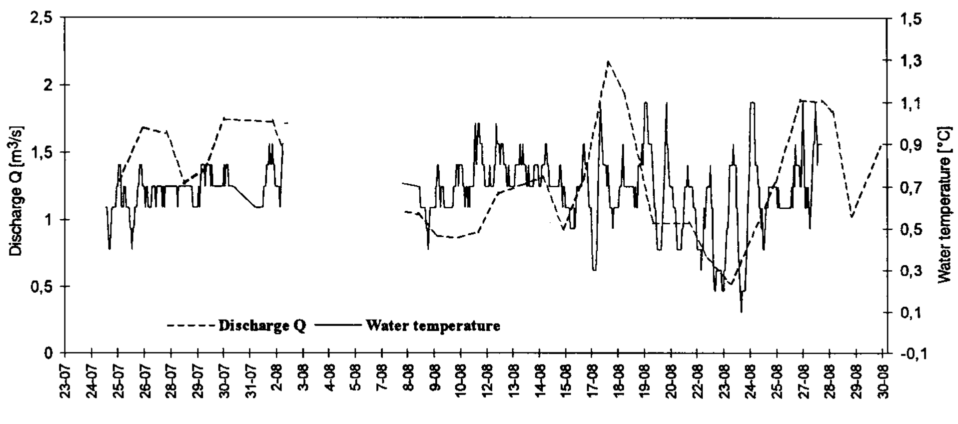

Fig. 10. Water temperature in the Waldemar River against discharge (Q) in summer 1998.

related to ablation, which is particularly visible in relation to the average 5-days' discharge and ablation (Fig. 9). High variability of discharge causes great morphometric changes of the riverbed and difficulties in measurements. Changeability of discharge of the Waldemar River is similar to the ones during the previous summers. Ablation is the main factor responsible for discharge. Strict dependence between ablation and discharge allows determining share of surface ablation in total runoff from a glacier. Significantly, the river reacts very quickly to all hydrological changes on the glacier: small distance results in slight delay only between maximum discharge and maximum ablation.

Distinct relation between water temperature in the Waldemar River and air temperature, and their relation to water discharge and ablation could be determined. The greatest discharge occurred when water temperature was the highest (Fig. 10) and this relation allows for treating water temperature as an indicator of ablation and time variation in its intensity.

Feeding and outflow from the ice-dam lake on a glacier plays significant role in regime of the Waldemar River. Ice-dam lakes influence much a runoff from the glacial catchment basin. They are water reservoirs, mainly with seasonal runoff (Grześ and Banach 1974). The lake on the Waldemar Glacier is located at the foot of a median moraine and its area is about 0.5 hectares. The lake is fed directly by meltwaters flowing out from the western, mainly frozen part of the glacier. As much as 38% of discharge from the Waldemar Glacier was estimated to come from the lake in summer 1998. This fact stresses a role of the ice-dam lake in feeding and shaping the Waldemar River.

From about 4,800,000 m^3 of water flowing out through the Waldemar River, 67% was estimated to come from surface ablation of the Waldemar Glacier, comparing with 60% during the previous summer. The other 33% means feeding with rain as well as with water from melting icings. The latter, thanks to detailed analysis of the runoff from the glacier, was assessed to 250,000 m^3, which makes up about 6% of outflow. Rainfall feeding in 1998 was 133,000 m^3 (about 3% of the outflow). Circulating englacial water seems to play an important role in river feeding. A discharge from the Waldemar River can be expressed with the following equation:

$$Q = A + W + H + N + R$$

where: Q – river discharge, A – surface ablation, W – englacial water, H – precipitation, N – water from melting of icings, R – local sources of feeding (*e.g.* water from streams on valley slopes). These relations indicate an important role of ablational feeding in regime of a glacial river.

Conclusions

There is tight correlation between river water temperature, discharge and ablation. During the analysed season a high average air temperature was observed. It resulted in increased ablation if compared to the previous seasons. The ablation is not greatly varied in time. Maximum total ablation reached 160–180 cm w.e. at 200 m a.s.l., and the lowest total ablation equal to 106 cm w.e. occurred at 350 m a.s.l. Ablation changeability with altitude enabled to present a scheme of ablation for three types of summer. Average air temperature and local glacier conditions were accepted as the main factors of ablation. The described scheme can be used for the other glaciers in Spitsbergen, having similar area and altitude.

Taking into account the whole research period, ablation of the Waldemar Glacier accounted for 120.5 cm w.e. in 1998 and was nearly two times higher than during the previous season. Basing on detailed analysis of ablation and discharge, similar time variation of both was observed. Catchment basins with ablation higher than discharge and the ones with discharge much higher than ablation were determined. This analysis allows therefore for estimating the englacial flow.

From about 4,800,000 m^3 in the Waldemar River in 1998, 67% comes from surface ablation on the Waldemar Glacier. During the previous summer this share was similar and accounted for 60%. The other most important sources of river feeding comprise melting of icings, precipitation and water runoff down the surrounding slopes.

References

BARANOWSKI S. 1977. Subpolarne lodowce Spitsbergenu na tle klimatu tego regionu. — Acta Univ. Wratisl., 393: 157 pp.

BARTOSZEWSKI S. 1998. Reżim odpływu rzek Ziemi Wedel Jarlsberga, Spitsbergen. — Wyd. UMCS, Lublin, 167 pp.

DOWDESWELL J. A., HAGEN J.O., BJORNSON H., GLAZOVSKY A. F., HARRISON W. D., HOLMLUND P., JANIA J., KOERNER R.M., LEFAUCONNIER B., OMMANNEY L. and THOMAS R. H. 1997. The mass balance of circum-arctic glaciers and recent climate change. — Quat. Res., 48: 1–14.

GRZEŚ M. 1997. Preliminary results of glaciological studies of Waldemar Glacier. — Spitsbergen Geogr. Expeditions, Polar Session, Lublin: 89–91.

GRZEŚ M. and BANACH M. 1984. The origin and evolution of the Goes Lake in Srrkappland, Spitsbergen. — Pol. Polar Res., 5 (3–4): 9–22.

GRZEŚ M. and SOBOTA I. 1997. Bilans masy lodowca Waldemara w roku bilansowym 1996/1997. — Sesja Polarna, Mat., Lublin: 19–22.

GRZEŚ M. and SOBOTA I. 1998. Waldemar Glacier mass balance in the 1996/1997. — Spitsbergen Geogr. Expeditions, Polar Session, Lublin: 41–50.

HAEBERLI W., HOELZE M. and BOSCH H. 1991. Glacier mass balance bulletin. — Bull., 1 (1988–1989), IAHS (ICSI)–UNEP–UNESCO.

HAEBERLI W., HOELZE M. and BOSCH H. 1994. Glacier mass balance bulletin. — Bull., 3 (1992–1993), IAHS (ICSI)–UNEP–UNESCO.

HAEBERLI W., HOELZE M. and BOSCH H. 1996. Glacier mass balance bulletin. — Bull., 3 (1994–1995), IAHS (ICSI)–UNEP–UNESCO.

HAGEN J.O., LIESTØL O., ROLAND E. and JORGENSEN T. 1993. Glacier atlas of Svalbard and Jan Mayen. — Norsk Polarinst., Oslo.

JANIA J. 1993. Glacjologia. — Wyd. Nauk. PWN, Warszawa, 359 pp.

JANIA J. 1994. Field investigations during glaciological expeditions to Spitsbergen in the period 1992–1994. —Interim Rp., Univ. Silesia, Katowice, 40 pp.

JANIA J. and HAGEN J.O. 1996. Mass balance of Arctic Glaciers. — IASC, Univ. Silesia, Sosnowiec–Oslo, 62 pp.

JOHN B.S. 1977. The ice age, past and present. — Collins, London, 254 pp.

KONOVALOV V.G. 1987. Methods of calculation and remote-sensing measurements for the spatial distribution of glacier annual mass balances. — J. Glac., 33: 212–217.

KRENKE A.N. and MENSHUTIN V.M. 1987. Calculation of mass balance of glaciers by remote-sensing imagery using similarity of accumulation and ablation isoline patterns. — J. Glac., 33: 363–368.

LANKAUF K.R. 1989. Lodowiec Waldemar, mapa. — Inst. Geogr. Uniw. M. Kopernika, Toruń.

LANKAUF K.R., 1993. Nowe dane o recesji lodowców regionu Kaffiøyry (Ziemia Oskara II, NW Spitsbergen). — Wyniki badań VIII Toruńskiej Wyprawy Polarnej Spitsbergen '89. UMK, Toruń, 113–129.

LANKAUF K.R. 1995. Lodowiec Waldemar, mapa. — Inst. Geogr. Uniw. M. Kopernika, Toruń.

LANKAUF K.R. and PREISNER Z. 1982. Geomorphology of the forefield of the Waldemar Glacier (Oscar II Land, NW Spitsbergen). — Ann. Univ. N. Copernici, 16: 52–59.

LESZKIEWICZ J. 1982. Dynamika odpływu powierzchniowego zlewni potoku lodowca Nordfall (południowy Spitsbergen). — Wypr. Polarne Uniw. Śl. 1977–1980, 543: 60–76.

LESZKIEWICZ J. 1987. Charakterystyczne cechy zlewni polarnych oraz próba modelowania statystycznego topnienia śniegu i odpływu ablacyjnego w zachodniej części Spitsbergenu. — Prace Nauk. Uniw. Śl., 920: 84 pp.

MARSZELEWSKI W. 1987. Wybrane zagadnienia hydrograficzne przedpola Lodowca Elizy (Ziemia Oskara II, NW Spitsbergen). — Ann. Univ. N. Copernici, 20: 107–125.

PELTO M.S. 1988. The annual balance of North Cascade Glaciers Washington, U.S.A., measured and predicted using an activity-index method. — J. Glac., 34: 194–199.

PIETRUCIEŃ C. 1977. Hydrological investigations of moraine lakes in the forefield of Aavatsmark Glacier. — Ann. Univ. N. Copernici, 13: 127–144.

PIETRUCIEŃ C., SKOWRON R. and LANKAUF K.R. 1987. Zmiany sieci hydrograficznej wywołane procesem recesji Lodowca Elizy w świetle zdjęć lotniczych i prac geodezyjnych. — Fotointerpretacja w badaniach polarnych, Uniw. M. Kopernika, Toruń, 73–85.

SKOWRON R. 1995. Dynamika temperatury wody i zasobów ciepła w meromiktycznym jeziorze strefy polarnej (NW Spitsbergen) w okresie lata polarnego. — XXII Symp. Polarne, Wrocław, 69–83.

SOBOTA I. 1997. Preliminary characterstics of outflow from the Waldemar Glacier (Kaffiøyraa, NW Spitsbergen) in the 1996 summer. — Wypr. Geogr. na Spitsbergen, Lublin: 157–162.

SOBOTA I. 1998. Ablacja i odpływ z lodowca Waldemara w sezonie letnim 1997. — Spitsbergen Geogr. Expeditions, Polar Session: 149–168.

SUGDEN D.E. and JOHN B.S. 1976. Glaciers and landscape, a geomorphological approach. — Edward Arnold, London, 376 pp.

SZCZEPANIK W. 1977. Selected problems in the hydrography of the catchment basin of the Waldemar River (West Spitsbergen, Oscar II Land). — Ann. Univ. N. Copernici, 13: 113–126.

VINCENT C. and VALLON M. 1997. Meteorological controls on glaciers mass balance empirical relations suggested by measurements on glacier de Sarennes, France.– J. Glac., 43: 131–137.

Received April 19, 1999
Accepted December 21, 1999

Streszczenie

Badania ablacji i dopływu prowadzono latem 1998 roku na lodowcu Waldemara na Równinie Kaffiøyra w północno-zachodniej części Spitsbergenu (fig. 1). Analizowany sezon charakteryzował się wysoką średnią temperaturą powietrza, co przyczyniło się do większej w porównaniu z poprzednimi sezonami ablacji. Ablacja wykazywała niewielką zmiennością w czasie (fig. 2). Maksymalna wartość całkowitej ablacji wyniosła 160–180 cm równoważnika wodnego na wysokości 200 m n.p.m., a najniższą całkowitą wartość ablacji odnotowano na wysokości 350 m n.p.m. (106 cm r.w.), (fig. 3, tab. 1). Gradient ablacji dla całego okresu badań wynosił tylko 10 cm r.w. na 100 m (fig. 4). Na podstawie szczegółowej analizy zmienności ablacji wraz ze wzrostem wysokości przedstawiono schemat tego zjawiska dla trzech typów sezonów letnich (fig. 5). Za czynnik mający największy wpływ na rozkład ablacji przyjęto warunki pogodowe w danym sezonie letnim, a w szczególności temperaturę powietrza. Biorąc pod uwagę cały okres badań ablacja lodowca Waldemara wyniosła 120,5 cm r.w. i była około dwa razy większa od sezonu poprzedniego.

W celu określenia odpływu cieków odwadniających poszczególne części lodowca, podzielono go na charakterystyczne powierzchnie bilansowe (fig. 6). Na podstawie szczegółowej analizy ablacji

tych powierzchni i odpływu cieków je odwadniających stwierdzono podobną zmienność czasową obu zjawisk. Wydzielono zlewnie, na których ablacja była większa aniżeli odpływ cieków oraz takie, gdzie odpływ cieków był znacznie większy aniżeli wskazywałaby na to wielkość ablacji (fig. 7). Analiza ta pozwala szacować wielkość przepływu inglacjalnego.

Rzeka Waldemara wykazywała w czasie dużą zmienność natężenia przepływu (fig. 8), ściśle związaną z wielkością ablacji lodowcowej, co szczególnie widoczne jest w odniesieniu do średnich wartości pięciodniowych przepływu i ablacji (fig. 9). Stwierdzono, że na około 4,8 tys. m^3 wody, jaka odpłynęła rzeką Waldemara, 67% pochodzi z ablacji powierzchniowej lodowca Waldemara. Pozostałe najważniejsze źródła zasilania rzeki to: wytapianie naledzi, opady deszczu i spływ wody ze stoków otaczających lodowiec.

Istnieje duża zależność pomiędzy temperaturą wody w rzece a wielkością przepływu. W okresach najwyższej temperatury wody stwierdzano również największe natężenie przepływu (fig. 10).