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Seasonal runoff forecast for Kangerluarsunnguaq near Nuuk/Godthåb, West Greenland

Roger J. Braithwaite

March 1990

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ØSTER VOLDGADE 10, 1350 KØBENHAVN K, DANMARK

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RESUMÉ (DANSK)

Et vandkraftværk skal måske bygges for at forsyne Nuuk/Godthåb med elektricitet fra midten af 1990'erne. Det er meningen, at værket skal forsynes med vand fra bassinet Kangerluarsunnguaq syd for Nuuk. Bassinet er kun i ringe grad gletscherdækket og gletschere har en lille indflydelse på forandringer i afstrømningen. Afstrømningen i tidsrummet fra juni til oktober er dog meget tæt knyttet til snepålejringen, som er målt på en lille gletscher i bassinet, og der er beregnet en korrelationsgrad på 0.84. Da akkumulations-data er til rådighed i maj, kan de bruges til at forudsige afstrømning for den følgende sommer. For eksempel var snepålejringen i maj 1989 usædvanlig lav, nemlig kun 0.45 m vand, og afstrømningen for sommeren 1989 skulle derfor også være lav, nemlig 93×10^6 m^3. Målinger af snepålejring vil fortsætte i adskillige år for at forbedre korrelationen med afstrømning. Prøveforudsigelser vil blive udsendt til interesserede parter.

ABSTRACT

A hydro-electric power station may be built to supply Nuuk/Godthåb with power from the mid-1990s. The station will use water from the Kangerluarsunnguaq basin south of Nuuk. The basin only has a slight glacier cover and glaciers have little effect on runoff variations. However, the June to October runoff is highly correlated with snow accumulation measured on a small glacier in the basin, i.e. a correlation coefficient of 0.84. As the accumulation data are available in May, they can be used to forecast runoff during the following summer. As an example, accumulation in May 1989 was exceptionally low, i.e. 0.45 m water, and the runoff for the 1989 summer should have been low also, i.e. 93×10^6 m^3. The measurements of accumulation will be continued for several more years to improve the correlation with runoff. Test forecasts will also be issued to interested parties.

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1. INTRODUCTION

Since the mid-1970s, investigations have been made on the feasibility of hydropower in Greenland. At first, emphasis was put upon large basins that could supply new energy-intensive industries (GTO, 1975). However, during the 1980s, the emphasis changed to the so-called "town basins" where hydropower would supplement the existing energy supplies for towns including Nuuk/Godthåb.

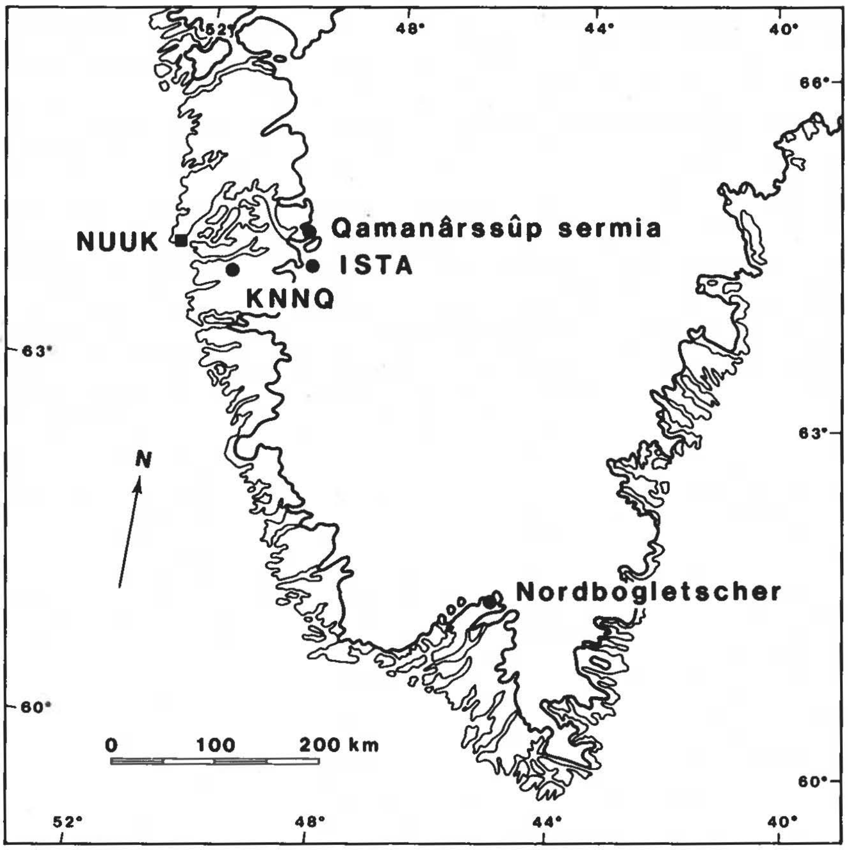

Fig. 1. Location of the Kangerluarsunnguaq and Isortuarsuup Tasia basins.

The planning of hydropower for Nuuk has been made in several stages, i.e. pre-feasibility (GTO, 1981), preliminary design (GTO, 1983) and feasibility (GTO, 1986), and a decision to build is expected soon with power generation to start in the mid-1990s. The planning studies included investigations of two basins south of Nuuk, i.e. the Kangerluarsunnguaq (KNNQ) and Isortuarsuup Tasia (ISTA) basins (fig. 1), but the first phase of operation will only use water from Kangerluarsunnguaq. As this basin has only slight glacier cover, in contrast to Isortuarsuup Tasia which includes many local glaciers and an extensive sector of the Greenland ice sheet, this might suggest that glaciers have little to do with hydropower for Nuuk. However, the present report shows that useful forecasts of seasonal runoff can be made using data from a small glacier in the Kangerluarsunnguaq basin.

2. THE KANGERLUARSUNNGUAQ BASIN

The lay-out of the Kangerluarsunnguaq (KNNQ) basin is shown in Fig. 2. The dotted lines indicate the hydrological boundaries of the various sub-basins (denoted by Roman numerals) which were identified during the planning process. The main area for exploitation will be sub-basin I although water may be transferred later from sub-basins II-V according to the feasibility study by GTO (1986).

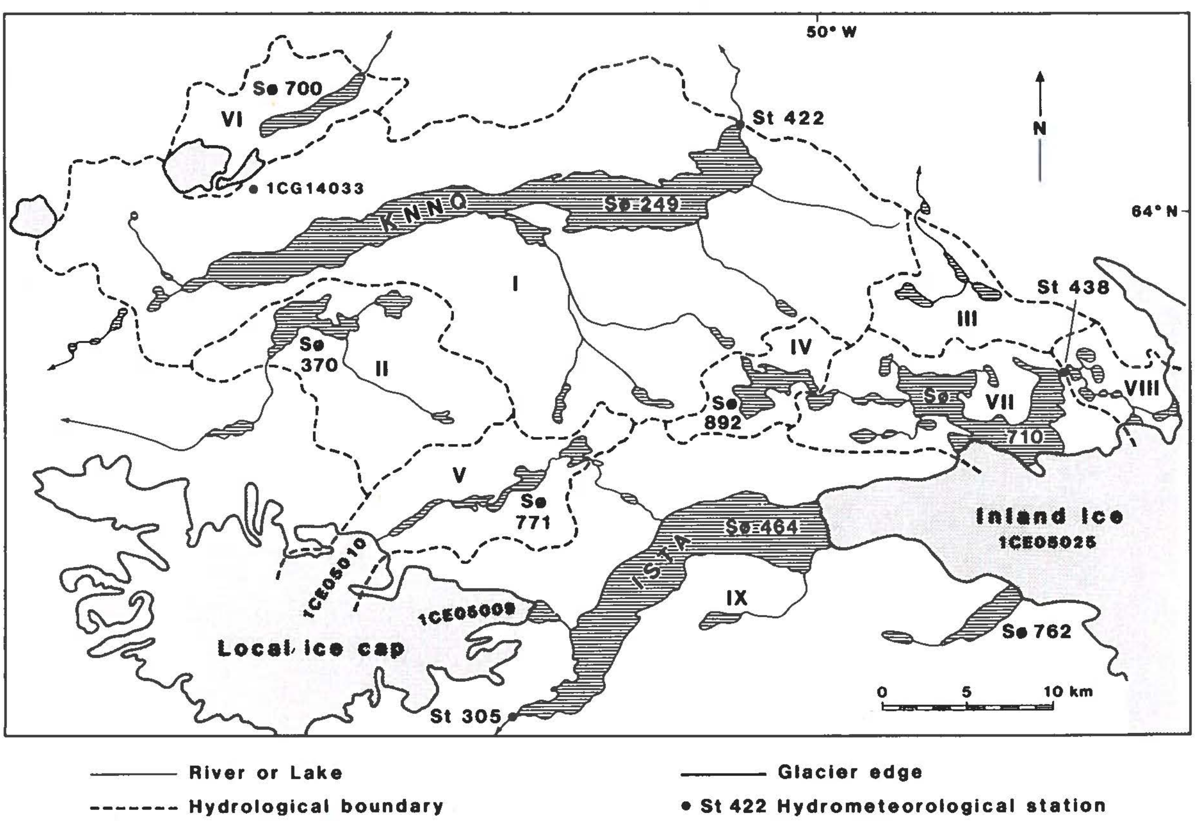

Fig. 2. Lay-out of the Kangerluarsunnguaq basin (KNNQ)

Recordings of runoff and climate were started in 1981 at St. 422 at the main outlet of sub-basin I as part of the pre-feasibility study (GTO, 1981). The drainage area of sub-basin I is 582 km^2 (GTO, 1986). Although glaciers only cover 1.8 percent of the total basin area (Weidick & Thomsen, 1983), simple mass balance measurements have been made on glacier 1CG14033 since 1982 (Braithwaite & Thomsen, 1989). The effect of glaciers on runoff is quantified by Braithwaite (1989; in press) who shows that runoff variations for Kangerluarsunnguaq are not significantly influenced by glaciers in contrast to the Isortuarsuup Tasia basin whose runoff is strongly influenced by glaciers.

3. POSSIBILITY OF FORECASTING

The problem of forecasting runoff can be illustrated by the seasonal variation of runoff in the Kangerluarsunnguaq (KNNQ) basin compared with precipitation in Nuuk (fig. 3). The curves refer to cumulative averages of monthly runoff and precipitation respectively. For purposes of comparison, the data are expressed as percentages of the respective annual averages.

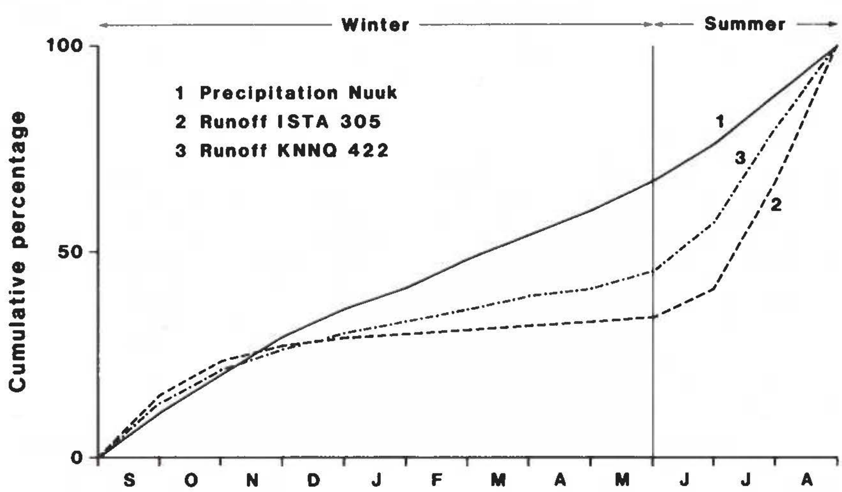

Fig. 3. Seasonal variations of runoff and precipitation

The precipitation curve is fairly straight through the winter but curves slightly upwards in the summer, indicating that precipitation is reasonably constant over the year with a slight summer maximum. By contrast, the runoff curve KNNQ only has a gentle upward slope through the winter, followed by a steep rise in the summer. Comparison of the runoff and precipitation curves indicates that most precipitation in November to May falls as snow until released by melting in June to August. The runoff curve for KNNQ 422 also has a slightly higher slope than the precipitation curve for September to October which may indicate continued snow melt as well as water release from storage in the main lake of the basin. Overall, the cycle of snow storage and meltwater release seems to be the main control on seasonal variations of runoff.

The November to May period covers over half of the year (58 %) but runoff is only about a quarter of the annual total (23 %). Annual runoff variations are therefore dominated by runoff variations for June to October. Much of this runoff comes from the melting of snow which is already stored in the basin during the winter. This suggests that measurements of snow storage in the spring could be used to forecast runoff during the following summer and, by extension, for the whole hydrological year. The theoretical requirements for this are discussed in the following section.

4. THEORY

The runoff from a basin is the volume of water flowing out of the basin in unit time. However, it is more convenient here to use the specific runoff which is the runoff per unit area in unit time, i.e. expressed in terms of water depth. The specific runoff q_t is given by the water balance equation:

$$q_t = \sum_{i=1}^{i=M} x_{it} \tag{1}$$

where x_{it} is the ith water balance component in the tth year, also expressed as water depths. The correlation between the runoff q_t and one of the water balance components x_{jt} is given by:

$$R(q, x_j) = \sum_{i=1}^{i=M} (S_i/S_q).R(x_i, x_j) \tag{2}$$

where S_i is the standard deviation of x_{it}. S_q is the standard deviation of q_t and $R(x_i, x_j)$ is the correlation between x_{it} and x_{jt}.

Equation (2) shows that the correlation between runoff and water balance component depends upon the variability of each component, as well as upon the correlations between components. In the special case that water balance components are independent of each other, $R(x_i, x_j)$ will be zero for $i \neq j$ and will be unity for $i=j$. This gives:

$$R(q, x_j) = (S_j/S_q) \tag{3}$$

where the correlation now depends only upon the variability of the water balance component compared with the runoff variability. This case is too simple as there are generally non-zero correlations between the water balance components. Negative correlations $R(x_i, x_j)$ reduce the correlation $R(q, x_j)$ while positive correlations increase it.

For the present, only the runoff for a few months in the summer is considered. The summer runoff is assumed to be:

$$q_t = p_t + c_t + (1-\alpha).e_t + \alpha.g_t \tag{4}$$

where α is the degree of glacier cover, p_t is summer precipitation, e_t is net evaporation from glacier-free areas, c_t is snow accumulation over the whole basin (=snowmelt) and g_t is ice melt from glaciers. Inter-annual changes of storage within the basin are neglected. Precipitation and snow accumulation are assumed to be uniform over the whole basin although this may be questionable. The evaporation e_t is probably small compared with precipitation p_t and its variations are neglected here.

The correlation of runoff with precipitation $R(q, p)$ is calculated by multiplying (4) throughout by p_t, averaging, and dividing throughout by the standard deviations of precipitation and runoff respectively:

$$R(q, p) = (S_p + S_c.R(c, p) + \alpha.S_g.R(g, p))/S_q \tag{5}$$

Similarly the correlation between runoff and snow accumulation is:

$$R(q, c) = (S_p.R(p, c) + S_c + \alpha.S_g.R(g, c))/S_q \tag{6}$$

while the correlation between runoff and glacier melt is:

$$R(q, g) = (S_p.R(p, g) + S_c.R(c, g) + \alpha.S_g)/S_q \tag{7}$$

where S_q, S_p, S_c and S_g are the respective standard deviations of summer runoff, precipitation, snow accumulation, and glacier melt.

The only correlation involving forecasting is the one between runoff and accumulation while the other two correlations refer to extra information on runoff which cannot be forecasted, and may even disturb the forecast.

5. DATA

The runoff data up to 1985 are published in GTO (1986, p. 76-87) while later data were kindly provided by Nuna-tek. There are few breaks in the records and there are many points on the discharge-rating curve. The quality of data is therefore high.

By contrast, there are some problems with the glaciological data due to missing observations for some stakes in certain years so that missing data have to be estimated. This is done by assuming separate time and space variations for stake data (Braithwaite & Olesen, 1989).

Data for accumulation at six stakes are shown in Table 1. There are almost complete data for stakes 2 and 7 except for 1981/82 while there are missing data for other stakes. The "Index" column in Table 1 refers to averages on all six stakes while the "Mean" row refers to averages for the three years when there are data for all six stakes. The index for other years is estimated by comparing the available data with the three-year means. For example, the accumulation at St. 1 in 1981/82 (0.48 m water) is 0.12 m water lower than the 3-year mean for that stake (0.60 m water) so that the accumulation index for 1981/82 is assumed to be similarly lower than the 3-year mean index (0.57 m water). Thus the accumulation index for 1981/82 is estimated at 0.45 m water. The procedure for other years with missing data is similar but with data for more stakes.

Table 1. Accumulation data on 6 stakes on Glacier 1CG14033 near Nuuk/Godthåb.

Year	St. 1	St. 2	St. 4	St. 5	St. 6	St. 7	Index
1981/82	0.48						(0.45)
1982/83		0.74		0.91	0.83	0.67	(0.80)
1983/84		0.70	0.76	0.93	0.89	0.56	(0.77)
1984/85	0.59	0.68	0.46	0.43	0.51	0.37	0.51
1985/86	0.56	0.96				0.65	(0.77)
1986/87		0.50	0.23	0.82	0.86	0.69	(0.62)
1987/88	0.82	0.78	0.81	0.88	0.95	0.31	0.76
1988/89	0.40	0.42	0.49	0.52	0.58	0.30	0.45
Mean	0.60	0.63	0.59	0.61	0.68	0.33	0.57

Units are m water
() Estimated

Data for net ablation at four stakes are shown in Table 2. There are complete data on all stakes except for 1982 when only one stake was established in spring 1982. The "Index" column in Table 2 refers to averages of four stakes while the "Mean" row refers to averages for the six years when there are data for all four stakes. The index for 1982 is estimated by noting that net ablation on stake 1 is +0.16 m water higher than the mean for the six years, i.e. 0.44 m water, and assuming that the index is similarly higher than the mean index for the six years.

Table 2. Net ablation at 4 stakes on glacier 1CG14033 near Nuuk/Godthåb

Year	St. 1	St. 2	St. 4	St. 7	Index
1981/82	0.60				(0.42)
1982/83	-0.03	-0.59	-0.62	-0.38	-0.41
1983/84	0.02	0.09	-0.03	0.36	0.11
1984/85	1.62	1.06	0.68	1.58	1.24
1985/86	0.58	-0.30	-0.14	0.44	0.15
1986/87	0.47	0.36	0.03	1.04	0.48
1987/88	-0.05	-0.07	-0.21	0.22	-0.03
Mean	0.44	0.09	-0.05	0.54	0.26

Units are m water equivalent
() Estimated

According to Braithwaite & Olesen (1989) the accumulation and ablation indices calculated above are the best estimates of the effect of climate on the data, i.e. they represent climate signals for accumulation and ablation respectively. They are therefore used for the correlations with runoff and precipitation reported in the following section.

6. RESULTS

The basic data used for the study are presented in Table 3 where the runoff data are expressed as specific runoff in m water. The precipitation data refer to precipitation in Nuuk/Godthåb. The mean and standard deviation s.d. at the bottom of the table now refer to 7 years of record.

Table 3. Basic data for KNNQ basin near Nuuk/Godthåb 1981-1988

Year		Runoff		Precip.	Accum	Glacier
	Winter	Summer	Annual	Summer	Spring	Melt
1981/82	0.06	0.18	0.24	0.29	(0.45)	(0.42)
1982/83	0.12	0.40	0.52	0.42	(0.80)	-0.41
1983/84	0.10	0.37	0.47	0.36	(0.77)	0.11
1984/85	0.06	0.16	0.22	0.30	0.51	1.24
1985/86	0.06	0.26	0.32	0.22	0.77	0.15
1986/87	0.07	0.29	0.37	0.33	(0.62)	0.48
1987/88	0.11	0.29	0.40	0.39	0.76	-0.03
Mean	0.08	0.28	0.36	0.33	0.67	0.28
s.d.	±0.03	±0.09	±0.11	±0.07	±0.14	±0.52

Units are m water

() Estimated

As a first step, correlation coefficients were calculated between summer runoff, summer precipitation, spring accumulation and glacier melt and the results are shown in Table 4.

Table. 4. Correlations of summer runoff with water balance elements.

	Runoff	Precip.	Accum.	Glacier
Runoff	1.00	0.66*	0.84	-0.82
Precip.		1.00	0.39*	-0.51*
Accum.			1.00	-0.78
Glacier				1.00

* Not significant at 5% level

There is a moderately high correlation between summer runoff and summer precipitation (r=0.66) which is not surprising as some of the runoff comes from rainfall in the summer. However, there is a reasonably high correlation (r=0.84) between summer runoff and snow accumulation which supports the present thesis on forecasting (correlation significant at less than 5% level).

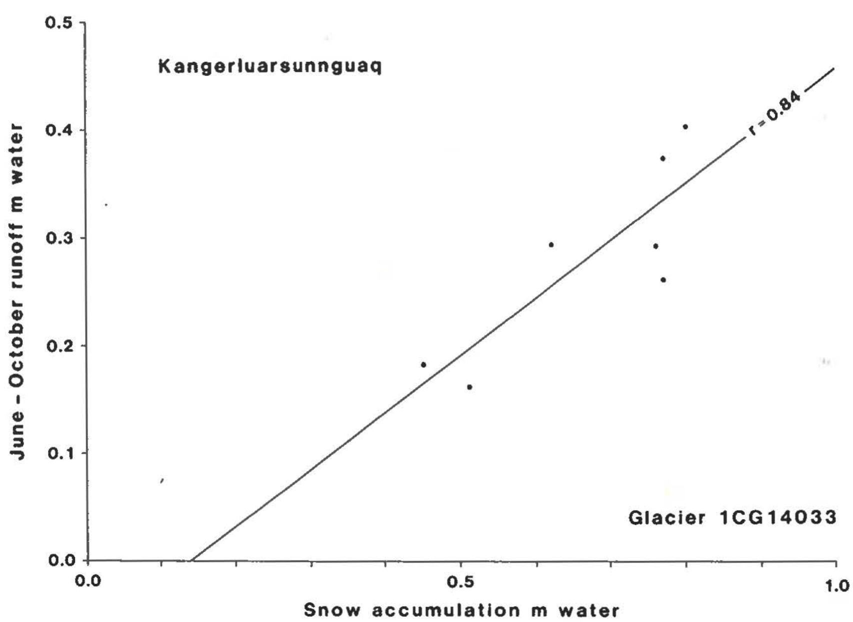

Fig. 4. Specific runoff for June to October versus snow accumulation

There is also a strong negative correlation (r=-0.82) between summer runoff and glacier melt (correlation significant at less than 5% level) which is similar to that found in Johan Dahl Land, South Greenland (Braithwaite &

Olesen, 1988a). The explanation from equation (7) is that R(q, g) depends on the runoff-precipitation and runoff-melt correlations which are both negative. More intuitively, increased glacier melt coincides with low snow accumulation (Braithwaite & OLesen, 1988b) while warm and sunny summers in Greenland tend to have low rainfall.

The simple regression equation relating summer runoff to summer precipitation is:

$$q_t = -0.01 + 0.88\ p_t \qquad r^2 = 0.45 \qquad (8)$$

where r^2 is the square of the correlation coefficient. This is a measure of the proportion of the runoff variance which is "explained" by the equation. Here, summer precipitation accounts for nearly half of the runoff variance. The corresponding equation for runoff and accumulation is:

$$q_t = -0.07 + 0.53\ c_t \qquad r^2 = 0.72 \qquad (9)$$

where the equation accounts for nearly three-quarters of the runoff variance. The equation is plotted together with the data points in fig. 4.

The combined effects of summer precipitation and snow accumulation are expressed by the multiple regression equation:

$$q_t = -0.18 + 0.52\ p_t + 0.43\ c_t \qquad r^2 = 0.84 \qquad (10)$$

The equation is not useful for forecasting but can be used as a check on the data. For example, the equation still leaves 16 % of the runoff variance "unexplained" of which at least a part must be due to errors. Also it was assumed in equation (4) that runoff is proportional to both precipitation and accumulation while the regression coefficients in (10) are much less than unity. This may be due to errors in the data but might also arise because precipitation and accumulation are not uniformly distributed in the basin. For example, the true average accumulation over the whole basin is probably much less than the accumulation on glacier 1CG14033 used here.

7. RUNOFF FORECASTING

Correlation between summer runoff and snow accumulation can be used to forecast summer runoff, i.e. for June to October, because the accumulation is already know in the spring, i.e. during May. Further calculations were also made to check the sensitivity of the forecast period, i.e. by correlating runoff for shorter periods with accumulation. The results are shown in Table 6 and fig. 5 in terms of runoff volumes.

Table 6. Intercept, slope and correlation for regression equations linking runoff for different periods to snow accumulation

Forecast period	Intercept 10^6 m^3	Slope 10^6 m^2	Correlation
June	-13	64	0.56
June-July	-30	159	0.75
June-August	-42	239	0.80
June-September	-47	289	0.83
June-October	-48	314	0.84
Year	-48	386	0.84

The runoff in June is not especially high and there is a poor correlation between June runoff and accumulation. This is because the release of snow in June is also controlled by temperature. For example, even if there is high snow accumulation there will only be high runoff if there is also high temperature. As the length of forecast period increases the runoff increases and the correlation with accumulation increases. This is because the controlling effect of temperature is reduced over a longer period, e.g. even in a cold summer there is more than enough energy to melt all the snow accumulation if one waits long enough, so that runoff is increasingly controlled by the amount of snow which is available for runoff.

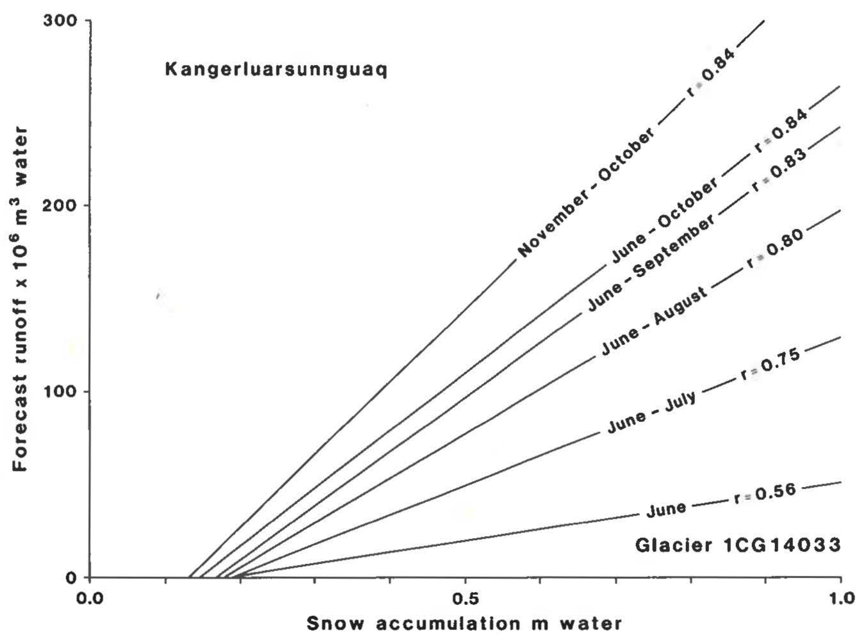

Fig. 5. Forecast runoff for various periods versus snow accumulation.

Observed runoff data for 1988/89 are not available for this study and a test "forecast" of the runoff can be made. The accumulation in May 1989 was measured to be 0.45 m water. Using Table 6, a value of 93 × 10^6 m_3 water can be estimated for the total runoff between June and October 1989. This value cannot be exactly correct for statistical reasons. For example, the 80% confidence interval around the forecast is ± 34 × 10^6 m^3 water according to the formula given by Kreyszig (1970, p. 301-304). This implies a four-in-five chance that the true runoff lies in the range 59 to 125 × 10^6 m^3 water. Taking account of this uncertainty, a forecast made at the end of May 1989 would have been cautiously phrased but would have warned of extremely low runoff, e.g. perhaps lower than the previous minimum in 1984/1985.

8. OUTLOOK

The present findings indicate that runoff can be forecast from accumulation measurements on glacier 1CG14033. The measurements should be continued for 2-3 more years to improve the correlation. Test forecasts will also be issued to interested parties in June of each year to advertise the method. Such forecasts of summer runoff could be useful information for operating hydropower for Nuuk/Godthåb in the future. For example, the operator needs to decide whether to use water for present power generation or to store it for later. As the planned reservoir for the Kangerluarsunnguaq basin is quite large, i.e. about four times the annual runoff volume, it will usually be possible offset water shortages by taking water from storage in the reservoir. However, excessive drawdown will make the lake look ugly, and may involve problems with bank erosion. This can be avoided by reservoir management using seasonal runoff forecasts.

ACKNOWLEDGEMENTS

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REFERENCES

Braithwaite, R. J. 1989. Glaciers and hydropower for Nuuk/Godthåb, West Greenland. *Open File Series Grønlands Geologiske Undersøgelse* 89/2, 49 pp.

Braithwaite, R. J. *in press*: Effects of glaciers on annual runoff south of Nuuk/Godthåb, West Greenland. *Rapp. Grønlands geol. Unders.*

Braithwaite, R. J. & Olesen, O. B. 1988a: Effect of glaciers on annual runoff, Johan Dahl Land, South Greenland. *J. Glaciol.* 117(34), 200-207.

Braithwaite, R. J. & Olesen, O. B. 1988b: Winter accumulation reduces summer ablation on Nordbogletscher, South Greenland. *Z. Gletscherkd. Glazialgeol.* 24(1988), 21-30.

Braithwaite, R. J. & Olesen, O. B. 1989: Detection of climate signal by inter-stake correlations of annual ablation data, Qamanârssûp sermia, West Greenland. *J. Glaciol.* 35(120), 253-259.

Braithwaite, R. J. & Thomsen, H. H. 1989: Improved accumulation measurements on Glacier 1CG14033 near Nuuk/Godthåb, West Greenland. *Rapp. Grønlands geol. Unders.* 145, 63-66.

GTO, 1975: Lokalisering af vandkraftressourcer på Grønlands vestkyst. København: *Rapp. Grønlands Tek. Org.*, 58 pp + Appendix.

GTO, 1981: Projektskitse for vandkraftanlæg ved Buksefjord, Nuuk/Godthåb. København: *Rapp. Grønlands Tek. Org.*, 34 pp + Appendix.

GTO, 1983: Foreløbigt dispositionsforslag for vandkraftanlæg ved Buksefjord, Nuuk/Godthåb. København: *Rapp. Grønlands Tek. Org.*, 55 pp + Appendix.

GTO, 1986: Vandkraftanlæg Nuuk/Godthåb, projektforslag. København: *Rapp.* Grønlands Tek. Org., 143 pp + separate Appendix.

GTO, 1987: Provinsebeskrivelse hydrologiske provins III, Nuuk. København: *Rapp. Grønlands Tek. Org.*, 212 pp.

Kreyszig, E. 1970: Introductory mathematical statistics. New York: John Wiley, 470 pp.

Weidick, A. & Thomsen, H. H. 1983: Lokalgletschere og Indlandsisens rand i forbindelse med udnyttelse af vandkraft i bynære bassiner. *Grønlands geol. Unders. Gletscher-hydrol. Meddr* 83/2, 129 pp.

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