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Changes in dynamics and runoff from the High Arctic glacial catchment of Waldemarbreen, Svalbard

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ABSTRACT

Since 1997, the runoff from the High Arctic catchment of Waldemarbreen has been recorded continuously at the gauging station located in northwest Spitsbergen, Svalbard. The analysis of the changes in dynamics and runoff from the glacial (polar) catchment of Waldemarbreen was made. One of the aims of this study was to try to determine how changes in the degree of the glaciation of the catchment influence the volume of the river discharge and runoff. This was found to be directly dependent on the percent glacier cover of the catchment and its changes. Changing the area and the volume of the glacier reduces the rate of the discharge, even when the intensity of melting does not change. Glaciological investigations of Waldemarbreen were taken between 1996 and 2009. The average ablation of Waldemarbreen varied from 64 to 137 cm w.e. during this time, while the average winter balance of this glacier was 50 cm w.e. During the summer season the mean discharge of the Waldemar River at the point which closed the glacier catchment in the years 1997–2009 was 1.0 $m^3 s^{-1}$ (541 mm). The average proportion of ablation within the runoff was 55%, and ranged from 30 to 77% during individual seasons. This study also examines selected elements which play some role in the dynamics of the glacial catchment of Waldemarbreen, for example icings or a moraine-dammed lake. It is the first such analysis for this region of Svalbard.

1. Introduction

Understanding the conditions that influence a glacial catchment, its structure and evolution, is of particular importance. Svalbard rivers and glacial catchments are still poorly known. For example, Bartoszewski (1998) made a very detailed analysis of the river regime of the drainage basins in the Wedel Jarlsberg Land. In his work, the main attention was centred on the runoff process from catchments of different sources of alimentation. He focused primarily on the origin of the runoff, its dynamics and relationship with other elements of the environment. Leszkiewicz (1987) estimated the runoff from selected glacial catchments on the basis of hydrological models. He also classified and characterized hydrological seasons on Spitsbergen. Hodgkins (1997) described in detail the hydrology of glaciers in Svalbard. A review of water balance studies was conducted by Killingtveit et al. (2003). A detailed analysis of physico-chemical processes occurring in the catchment of a glacier and in a glacial catchment was made by Głowacki (2007).

These studies concentrated on the hydrological regime of rivers in some summer seasons. More comprehensive analyses relating to the changes in the whole catchment area and the impact of the deglaciation intensity on the rate of runoff in a multi-annual period were less frequently undertaken.

Studies of the Waldemar River have been undertaken by Szczepanik (1993); Pietrucień and Szczepanik (1982); Sobota (2000, 2005a) and Sobota et al. (2010). These concerned the regime of the river runoff, thermal characteristics of its waters, and the runoff structure only in selected summer seasons.

The main source of water in glacial rivers in the High Arctic is melting ice (Hodgkins, 1997; Bartoszewski, 1998; Hodgkins, 2001; Rachlewicz, 2009; Sobota et al., 2010). Measurements of river runoffs, especially the ablation component of their source glacier mass balance are an essential element of glaciological research. The amount of water carried by streams flowing from a glacier is closely related to the amount of ablation (Sobota, 2000, 2005a; Milner et al., 2009).

The vast majority of the volume of the water, as much as 85–90%, outflows from the glacial catchments of the High Arctic during the polar spring and summer (Leszkiewicz, 1987; Bartoszewski, 1998; Rachlewicz, 2009). Little runoff is also recorded in winter, as evidenced by frequent icing covers (Grześ and Sobota, 2000; Sobota, 2009, 2011). The runoff along the glacial river is strongly dependent on the conditions of glacial melting, and is the sum of rapid and delayed runoffs (Collins, 1979).

Water is stored in glaciers in the form of snow (short-term reservoir) and ice (long-term reservoir), and is released by melting after some delay (Kaltenborn et al., 2010). On an annual time scale, the water that comes from a glacierized catchment is the sum of the precipitation and the melted snow and ice (minus some evaporation). Both contributions can have a pronounced seasonality and will thus strongly vary by region and degree of glacierization. On a decadal time scale, change in the long-term reservoirs will also have an impact on runoff

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characteristics, as a diminishing glacier cover will produce less meltwater. The influence of glaciers on seasonal distribution of river flow is strongly dependent on annual temperature and precipitation cycles, and the proportion of the degree of glaciation of catchment (Kaltenborn et al., 2010).

The main aim of the project was the analysis of the changes in dynamics and runoff from the glacial (polar) catchment of Waldemarbreen in 1997–2009. One of the aims of this study was to determine how changes in the glaciation of the catchment influence the river discharge and total runoff — it was determined that they are directly dependent on the degree of glaciation in the catchment and its changes. Changes in area and volume of the glacier reduce the magnitude of the discharge, even when the intensity of melting does not change. It is the first such analysis for this region of Svalbard.

The studies of the Waldemar River runoff are closely linked with the glaciological research on Waldemarbreen. Glaciological research at Waldemarbreen has addressed the following issues: glacier melting, changes in snow thickness during winter and summer, and temporal changes in the area and location of the glacier tongue and mass balance. Estimation of the mass balance of Waldemarbreen has involved repeated point measurements at the glacier surface to determine the rates of summer ablation and winter accumulation. This approach involves estimating the local mass balance using ablation poles and snow thickness measurements, supplemented with studies of the snow cover in pits.

The results of the mass balance studies of Waldemarbreen are quite similar to other Svalbard glaciers which terminate on land (Sobota, 2000; Hagen et al., 2003; Sobota, 2005b, 2007a,b; Zemp et al., 2008; Haeberli et al., 2009).

2. Study area

Waldemarbreen is located in the northern part of Oscar II Land, Kaffiøyra, northwest of Spitsbergen (Fig. 1). Kaffiøyra is a coastal

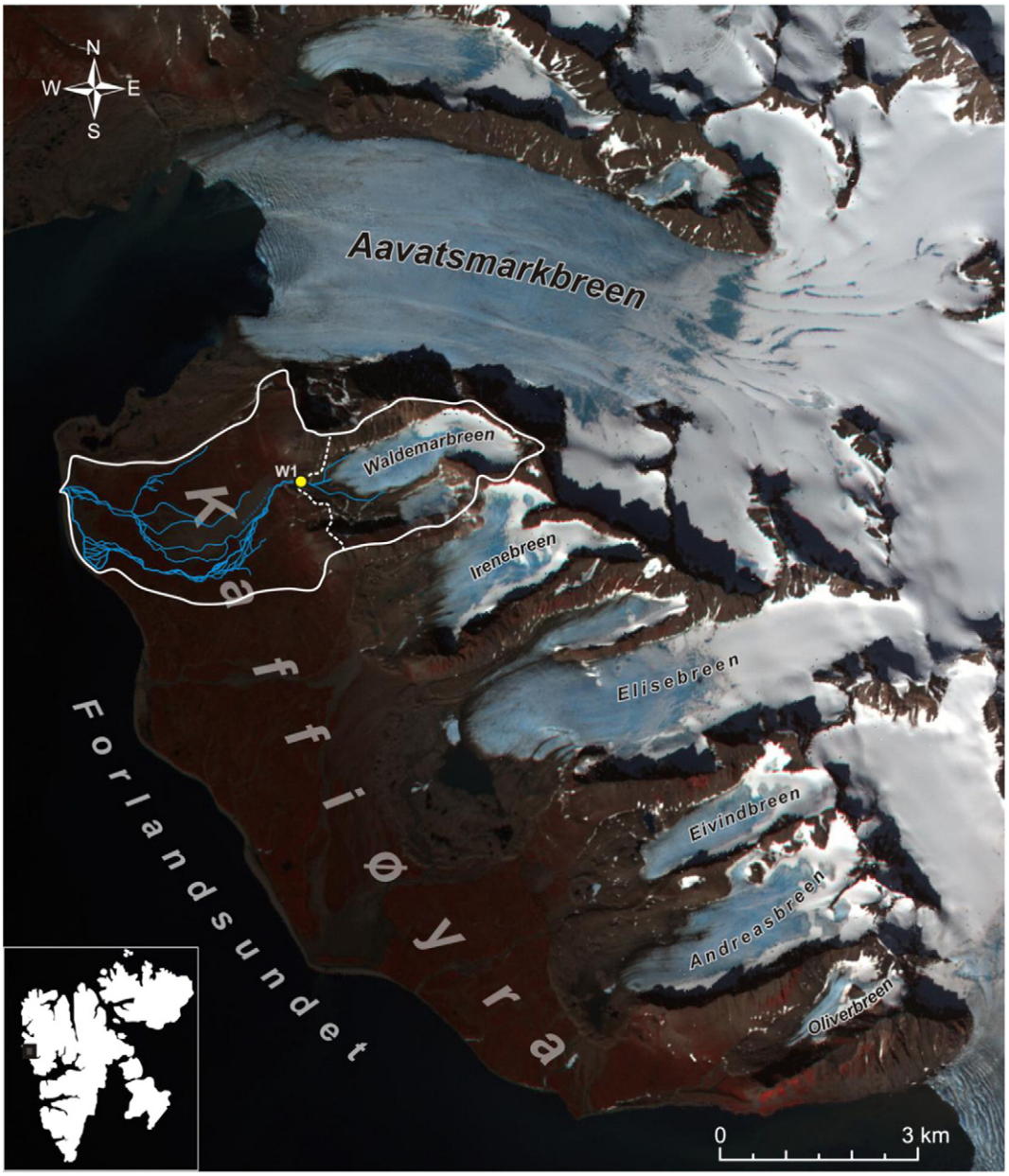

Fig. 1. Location map of Waldemarbreen and the Waldemar River catchment, Svalbard. W1 — gauging site. Based on the map prepared by M. Król and M. Ćmielewski.