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Measurements of selected water balance components in Ebbaelva catchments, Svalbard – pilot study

Marek Marciniak*, Anna Szczucińska
Institute of Physical Geography and Environmental Planning, Adam Mickiewicz University, Poznań, Poland

Krzysztof Dragon
Institute of Geology, Adam Mickiewicz University, Poznań, Poland

Introduction

The research of the water balance in polar catchments are relative unique. The water balance components are often estimated approximately or calculated using conceptual models. Killingtveit et al. (2003) reviews and summarizes all known previous water balance studies in Svalbald and give only several examples of water balance computation in unglaciated catchments. The water balance research was also undertaken in region of Bellsund (Bartoszewski 1988) and Horsund (Pulina et al. 1984). Even more difficult to recognize is water balance calculated for glaciated catchments, where the intensive water circulation take places only in summer months. In the remaining part of hydrologic year water circulation is connected with solid phase of water (sublimation, glacial retention, etc.). Moreover, in case of examination of water balance in polar catchments the complexity of this type of environment should be taken into consideration (e.g.: retention of water connected with permafrost, the seasonal effects connected with polar day and night, snow driffing between catchments, irregular locations of polar meteorological stations and its seasonal functioning in summer period.

The water balance formula includes the following water circulation components:

$$P = E + Qr + Qp + Qg + \Delta R \quad (1)$$

where:
P – precipitation [mm],
E – evaporation [mm],
Qr – river runoff calculated for catchments area [mm],
Qp – superficial runoff calculated for catchments area [mm],
Qg – groundwater flow calculated for catchments area [mm],
ΔR – retention changes [mm].

The aim of this study is computation of the water balance components which are the most unique estimated in polar environments: actual evaporation and groundwater flow. The methods of research are illustrated by the result of pilot studies performed in Ebbaelva catchments in Svarbald.

The Study area

For the pilot studies (in 2005 and 2006) and for research planned in the 2007 summer season a glaciated catchment of Ebba River (Ebbaelva) was selected. The river enters Petunia bay (Petuniabukta) – part of Billefjorden, in central Spitsbergen (Fig. 1). The catchment (51.5 km^2) consists of Ebba valley (Ebbadalen), which is covered in more than 50% by Ebba and Betram glaciers (Ebbabreen and Bertrambreen). Their meltwaters are the main supply of the Ebba River, which also collects waters from several streams flowing down from mountain ridges in the north and south. The average summer discharges of the Ebba River are between several and 20 m^3s^{-1}. The Ebba glacier belongs to polythermal type, so water outflows are active also in

* e-mail: mmarc@amu.edu.pl

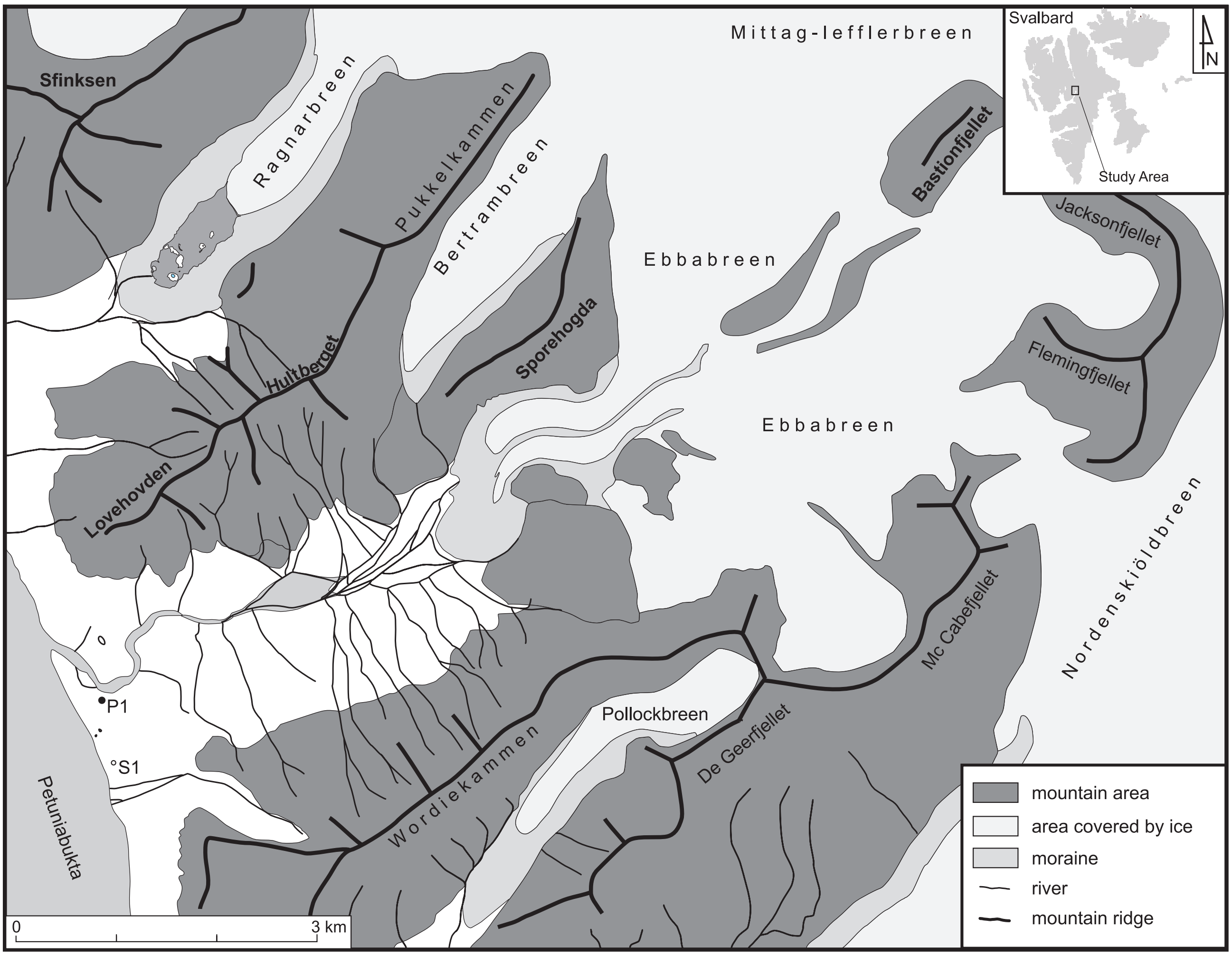

Fig. 1. The study area

winter time (Rachlewicz 2003a; Gibas et al. 2005). The catchment was previously often investigated, for instance, in regard to water discharge (Kostrzewski et al. 1989; Choiński 1989; Rachlewicz 2007) and meteorological conditions (Kostrzewski et al. 1989; Rachlewicz 2003b, c). The most of the catchment is in permafrost zone. The maximum active layer thickness is at the end of summer and may reach even 2 m (Gibas et al. 2005) – it makes existence of groundwater component of the Ebba River supply being very likely.

Methods and examples of their applications

Measurements of evaporation from free water surface are taken with an evaporation pan fixed within a measuring station (Figs. 2, 3). The main element of the measuring station is a pan (A) filled with water, of surface area about 1 m^2. Its upper rim should be installed slightly above land surface. A detail measurement of water surface elevation in the pan at the beginning and end of the period of observation allows assessment of the evaporation. The measurement is taken in a limnometric well (B). Its main part is a 4 cm in diameter pipe (B3), which is placed vertically on a base disc (B1) in the pan. For levelling of the base disk is used a level (B2) installed on it. The well is submerged in water, in such a way that free water surface is more or less in a half of its height. The main purpose of using the well is to eliminate water surface waving. In the well is a vertically installed sharp ended micrometric screw (B4). A male screw of the micrometric screw has vertical distance between spiral ridges of 1 mm. In consequence, screw rotation of 3.6 o gives vertical displacement of 0.01 mm. On the upper rim of the well is mounted a turn buckle (B6) and scale (B5). A task for an investigator is to recognize moment when the sharpened end of the screw (B4) touches the water surface and to read its position on the scale (B5).

It is very difficult to take precise daily measurements of the evaporation due to very small changes in water surface position in the pan. It is the reason for reporting and analyzing at least 10 days or two weeks sums of the evaporation. Additional difficulty during the interpretation of the results is a necessity of taking into account a correction for rainfall. It requires to take measurements of the rainfall with precision of at least the same accuracy as the measurements of evaporation.

In polar conditions the evaporation is smaller so its measurements are even more difficult. It is the reason for proposed below four major modifications of the evaporation pan for polar conditions. These modifications are results of experience gained during a pilot measurement series taken in Ebbadalen in summer 2006.

- First of all it is necessary to eliminate possibility of refilling water in the evaporation pan (A) through rainfall or snowfall. Correction for precipitation of the evaporation measurements requires to take measurements of the precipitation with precision of at least the same accuracy as the measurements of evaporation, which is unrealistic taking into account commonly used rain gauges. It is suggested to install a kind of tarpaulin roof (E) of area significantly bigger than the evaporation pan (A) on at height of 1 m above it. The roof will be installed on stakes (F) and fixed with ropes (G). It will unable rain water to reach the evaporation pan even during oblique direction of rainfall but will allow free air movement above water in the evaporation pan.
- Secondly, during taking the measurements in the evaporation pan a cover (C) should be placed on it to eliminate waving of the water surface due to wind. During the pilot studies such a waving, caused by even very fair wind, made the correct reading of the water surface elevation impossible. In the cover a window made of plexy and small opening will be left to make possible the observation and operation of the micrometric screw. Except of the time of the measurements the cover should be displaced.
- Thirdly, the sharp end of the micrometric screw should be equipped in electronic system for optical and acoustical signalization (D) of the moment of contact with water surface. For the confidence of an observer the system should be mounted on the cover (C). It will help to eliminate difficulties in determination of the moment of reaching the water surface by the screw, which exists in classical evaporation pan.
- Fourth, the evaporation pan (A) should be covered with a net, which will protect the pan from birds and other animals (damage, drinking water etc.). The net shall not influence the evaporation.

All of the above listed improvements should make the field measurements of daily sums of evaporation possible in polar conditions during summer. Laboratory tests proved that evaporation pan has sufficient measurement resolution for such a purpose.

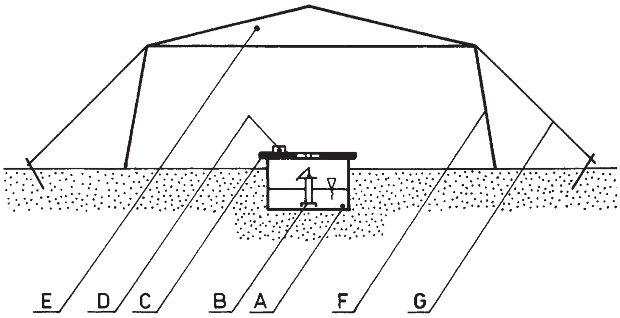

Fig. 2. Polar evaporymeter in the field position
A – evaporation pan, B – limnometric well with a micrometric screw, C – cover, D – electronic contact indicator, E – tarpaulin roof, F – stakes of roof, G – tighten rope

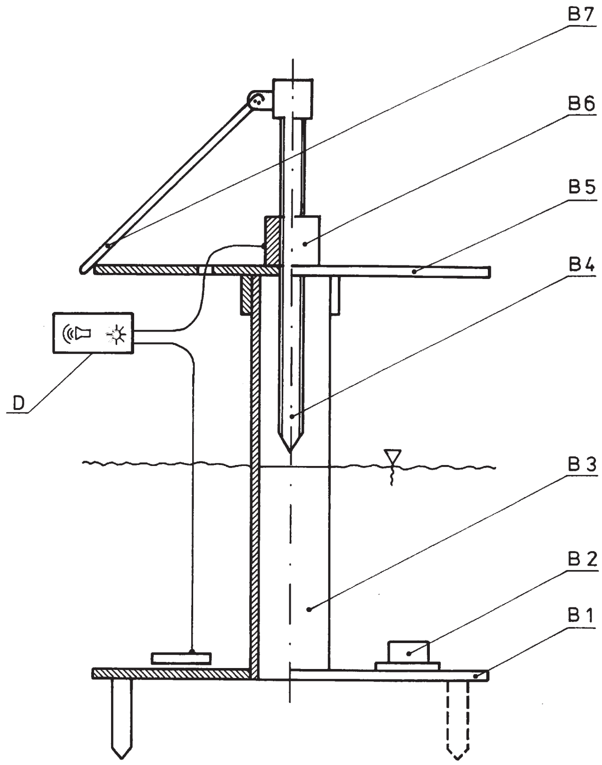

Fig. 3. Limnometric well of the polar evaporymeter
B1 – the base disc with tree leveling screws, B2 – spirit level, B3 – pipe of limnometric well with a linear scale, B4 – micrometric screw, B5 – angle scale, B6 – a nut of micrometric screw, B7 – pointer, D – electronic contact indicator

The groundwater flow measurements

For estimation of groundwater level fluctuations in the Ebbaelva River catchment the 0,7 m deep piezometer P1 was installed. This piezometer was located about 10 m from stream channel near the river mouth (Fig. 1). In this region sands and gravels filling the river valley during drilling were detected. The daily measurements of water level in the period between 15.08.2005 and 20.09.2005 were performed. Also the water level fluctuations in the river and run-

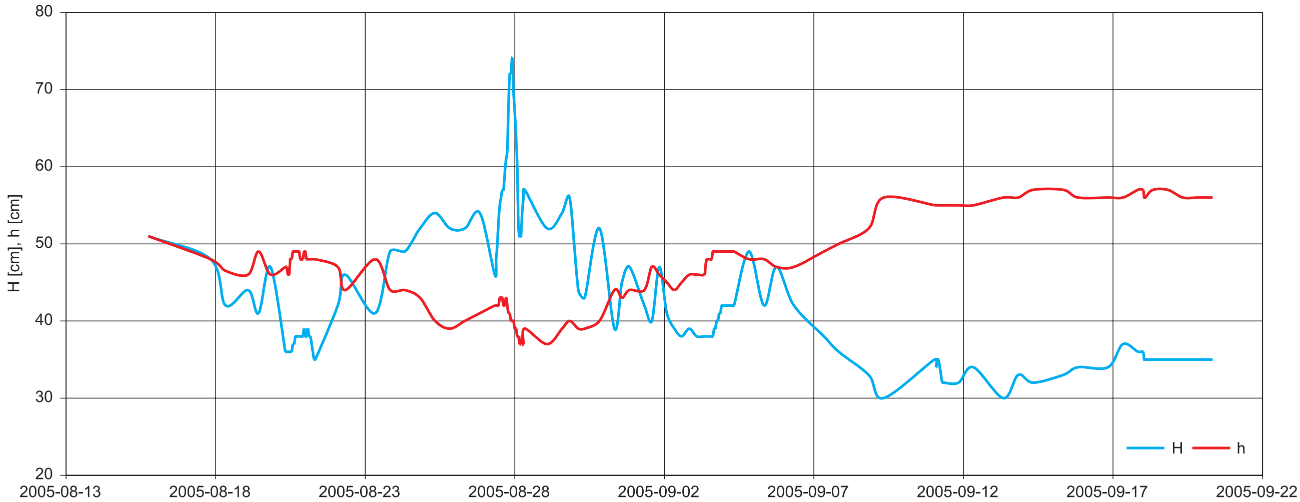

Fig. 4. Variations of free groundwater surface depth (h) and water level in Ebba river (H) during summer season 2005

off in this some period were measured. The result of this research on Fig. 4 is presented.

The strong relationship between subsurface water level fluctuations and stream regime are observable. The fluctuations of groundwater level indicate that groundwater flow play important rule in water circulation in Ebbaelva catchments especially in the stream channel vicinity.

Conclusions

The specific nature of polar environments cause that the measurements of water balance components are scarce. It is relating mainly to actual evaporation and groundwater flow. The pilot study performed in Ebbaelva catchments (Spitsbergen) show distinct groundwater water level fluctuations. These fluctuations prove that groundwater flow play important role in water circulation in this catchments. The test of evaporation with use of basin evaporometer shows that this apparatus should be adapted to specific polar environment. The detailed research of groundwater flow and actual evaporation will be performed in Ebbaelva catchments in summer 2007.

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