SHORT COMMUNICATION

Water Storage in Snow Cover and Runoff in Experimental Basins in the Jizerské hory Mountains

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Abstract: The main aim of this work was to compare the results of the water storages obtained in the experimental basins in the Jizerské hory Mountains before the time of snowmelt with the total outflows, which were measured in the hydrological stations during the snowmelt period in two winter seasons with extraordinary snow depths (2005 and 2006). The snow water equivalent (measured in weekly steps), daily precipitation amount, and runoff in hourly values were the input data; the calculated runoff coefficients were the output values. The runoff coefficients from the snowmelt periods of 2005 and 2006 were compared in the Uhlířská and the Jezdecká Basins. The runoff coefficient in the Uhlířská Basin increased in 2006 from 0.636 to 0.688 (increase by 4%) and in the Jezdecká Basin it increased in 2006 from 0.660 to 0.749 (increase by 9%). It may have been the result of a bigger volume of precipitation during the snowmelt period 2006. The calculated runoff coefficients, which express the differences between the water storage obtained and the total outflow, can describe the specific characters of the experimental basins. It may be useful for the estimation of the expected inflow into water reservoirs and also for the hydrological forecasting in the foothills of the Jizerské hory Mountains. The measured data of snow cover also serve as a check, and also for the possible adjustment of the snow water equivalent generated by the model SNOW 17 – which is a part of the forecasting modelling system Aqualog. This system is in everyday use for the Elbe river forecasts in the Forecasting Centre of CHMI. The usefulness of this procedure was proved especially during the floods arising from snowmelts in last years. The model SNOW 17 has been calibrated for the catchment of the Černá Desná Stream with the Jezdecká closing profile (one of the experimental basins in the Jizerské hory Mountains). The results obtained demonstrate a very good capability of the model to duplicate the dynamics of the snow cover accumulation and thaw, if quality input data are available.

Keywords: snow water equivalent (SWE); runoff coefficient; snowmelt; simulation of discharge

The climatological stations Desná-Souš and Bedřichov-dam that belong to the CHMI (Czech Hydrometeorological Institute) basic observation network are situated in the Jizerské hory Mountains at the elevation 772 m and 774 m a. s. l. The measurements of the snow depth and snow water equivalent in these stations are not quite representative for the upper part of the Jizerské hory Mountains, which reach up to 1126 m a. s. l. The data from these two stations were insufficient for

the evaluation of water storage in the snow cover for forecasting the water inflow volume into the reservoirs in the Jizerské hory Mountains during the snowmelt period. On this account, the regular measuring network of the snow cover was established at the end of 70's in the basin of the Josefův Důl Reservoir. The measuring network of the snow cover was also extended into seven experimental basins, which were established in the Jizerské hory Mountains at the beginning of 1980's.

Since 1991, a stable measuring network with twenty-eight snow sites has been used. The elevation ranges from 756 m to 997 m a.s.l. The pair sites, which means under the canopy and on the clearings, are being observed in eight localities. The measuring is practiced regularly in weekly time steps. The measured data are used to create the maps of the snow depths and snow water equivalents every week.

The main aim of this work was to compare the results of the water storages obtained in the experimental basins before the time of snow melt with the total outflows, which were measured in the hydrological stations during the snow melt periods in two winter seasons (2005 and 2006) with extraordinary snow depths. The differences between the water storage obtained (plus precipitation during the snowmelt period) and the total outflow could describe the specific character of each of the seven experimental basins. It could be useful for the estimation of the expected inflow into water reservoirs and for hydrological forecasting in the foothills of the Jizerské hory Mountains. The article attends in detail to the experimental basins Uhlířská and Jezdecká.

Experimental basins in the Jizerské hory Mountains

The experimental basins in the Jizerské hory Mountains were established at the beginning of the 1980's as a result of the forest devastation (by acid rain). The aim of the research is to gain data for the quantification of the runoff conditions changes in the changing environment. The research is focused on seven experimental catchments (Uhlířská, Blatný rybník, Kristiánov, Smědava I and II, Jizerka and Jezdecká) with areas from 1.87 km^2 to 10.6 km^2 and at elevations from 700 m a.s.l. to 1100 m a.s.l. The basins Jezdecká and Uhlířská are part of the international partnership ERB (Experimental and Representative Basins).

The Uhlířská Basin on the Černá Nisa Stream lies in the western part of the Jizerské hory Mountains. The basin area is 1.87 km^2, the highest point is Olivetská hora Mountain 886 m a.s.l., and the closing profile elevation is 776 m a.s.l. The stream length is 2.1 km and the average stream slope is 2.3%. The annual average precipitation on the basin is 1400 mm, the annual average temperature is 4.6°C, and the annual average discharge is 0.063 m^3/s. The basin is in operation since the year 1982. The water level gauging station (776 m a.s.l.) is situated on the Černá Nisa Stream, flowing into the Bedřichov Reservoir. There are also one climatological station (822 m a.s.l.), three

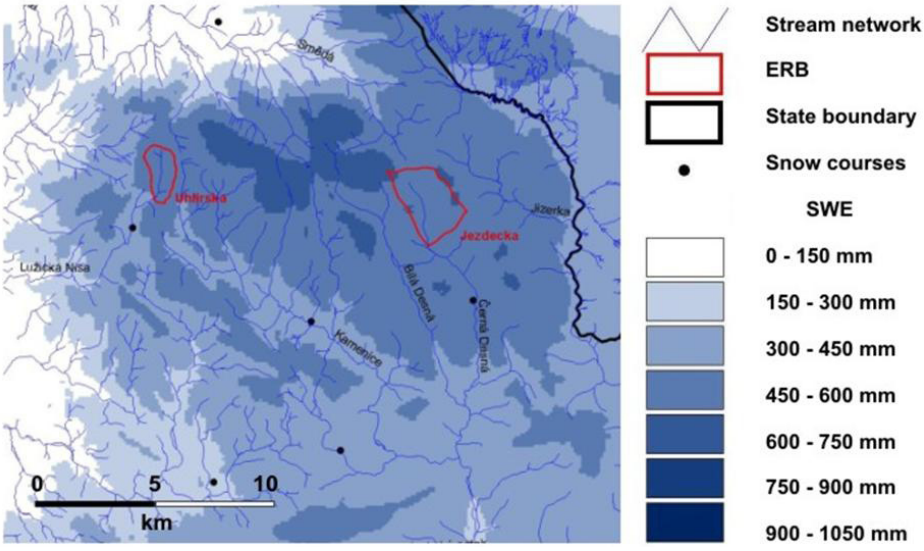

Figure 1. Snow water equivalent (SWE) – the upper Jizera Basin (March 13, 2006); without the use of the data measured in snow profiles in CHMI experimental basins

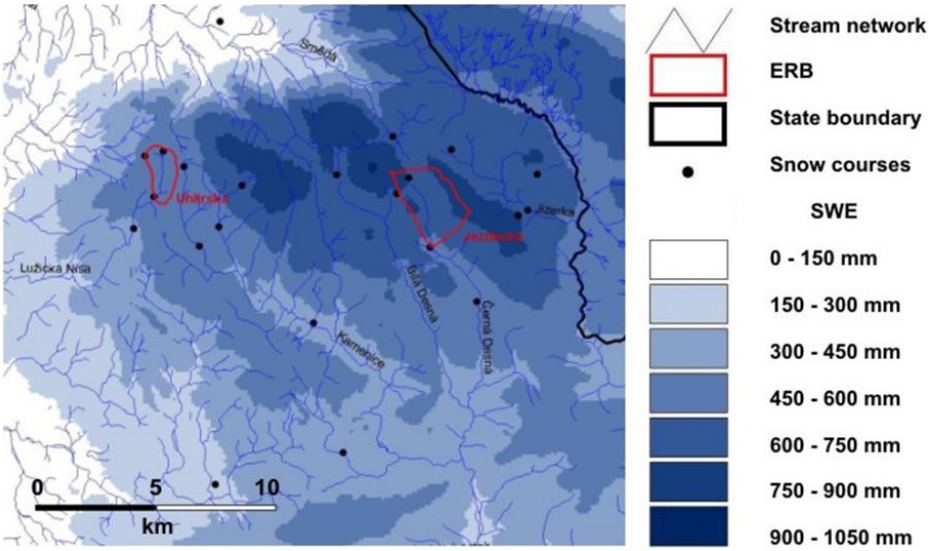

Figure 2. Snow water equivalent (SWE) – the upper Jizera Basin (March 13, 2006); with the use of the data measured in snow profiles in CHMI experimental basins

automatic rain gauges (777–855 m a.s.l.), and also five snow sites during winters.

The Jezdecká Basin on the Černá Desná Stream lies in the eastern part of the Jizerské hory Mountains. The basin area is 4.75 km^2, the highest point is Černý vrch Hill 1025 m a.s.l. and the closing profile elevation is 775 m a.s.l. The stream length is 3.1 km and the average stream slope is 3.6%. The annual average precipitation on the basin is 1500 mm, the annual average temperature is 4.9°C and the annual average discharge is 0.190 m^3/s. The basin has been in operation since the year 1982. The water level gauging station (775 m a.s.l.) is situated on the Černá Desná Stream, flowing into the Souš Reservoir. There are also one climatological station (867 m a.s.l.), three automatic rain gauges (778–917 m a.s.l.), and also six snow sites during winters.

MATERIAL AND METHODS

Calculation of maximum of snow water equivalent (SWE) before spring snow melt in the years 2005 and 2006

2005. The maximum of the snow depth and its water equivalent (SWE) in the whole area of the Jizerské hory Mountains were measured on March 14th 2005 (Pobříslová *et al.* 2006). The map of SWE for this day is shown in Figure 3. The map construction was based on the measurements of SWE in twenty-eight experimental snow sites,and on the measurements in other climatological stations in the region of the Jizerské hory Mountains and their foothills (Řičicová *et al.* 2006b). The map was created by the interpolation of the

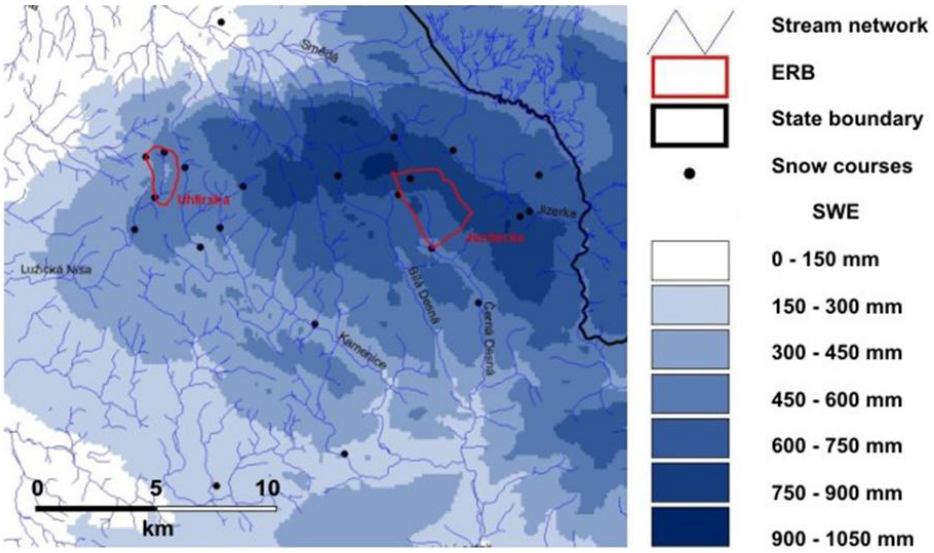

Figure 3. Snow water equivalent (SWE) – the upper Jizera Basin (March 14, 2005); with the use of the data measured in snow profiles in CHMI experimental basins

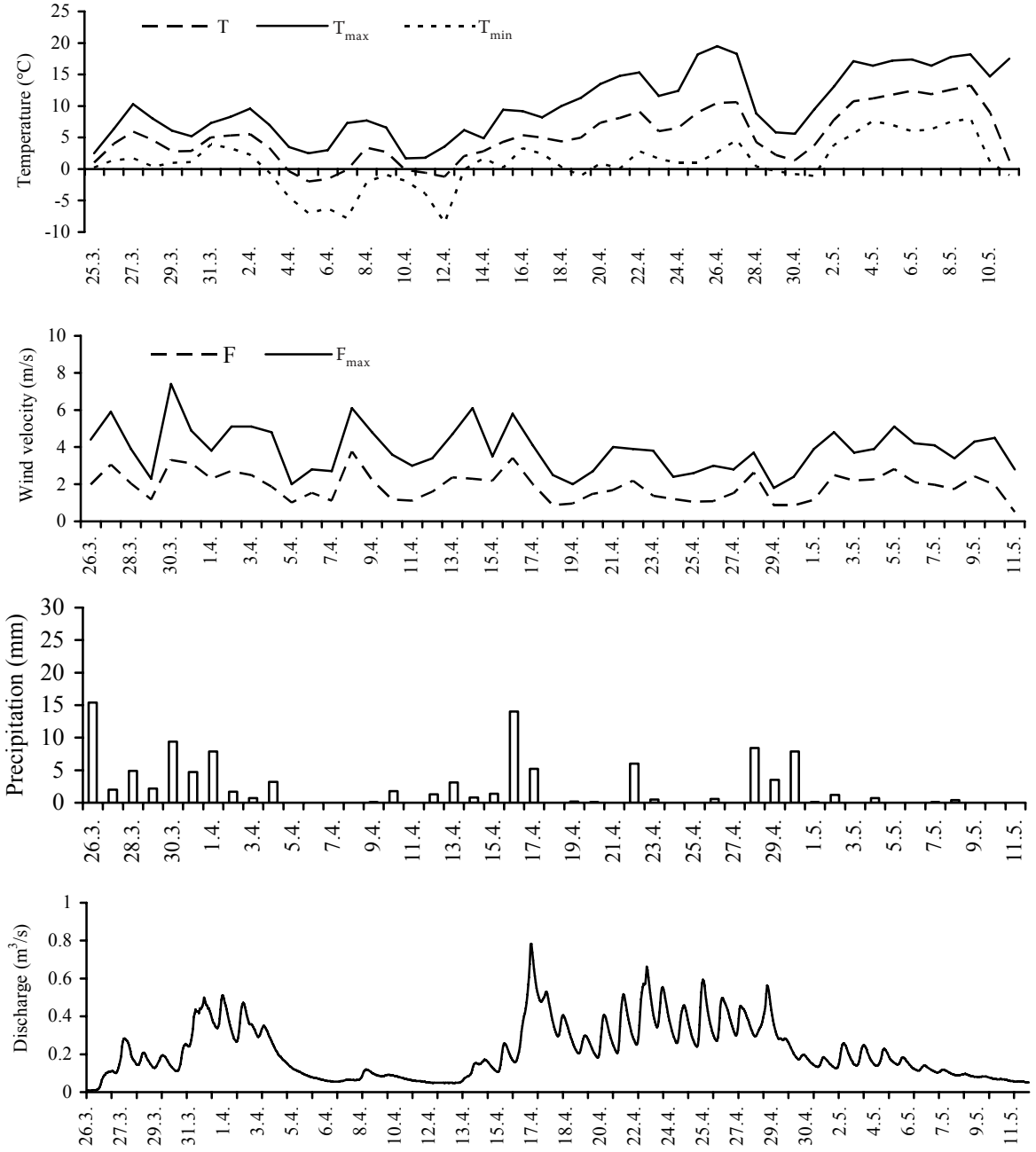

Figure 4. The Uhlířská Basin 2006 – the course of climatic characteristics and runoff during the snowmelt period 2006 (Pobříslová *et al*. 2007); the first diagram represents the course of air temperature – average, maximum, and minimum from the climatological station Bedřichov-dam; the second diagram represents the wind velocity – average and maximum; the third diagram represents the daily amount of precipitation and the fourth diagram represents the runoff course

measured data using universal linear kriging. The mean SWE values for March 14th were calculated from the map. The SWE was in the Uhlířská Basin 492 mm and in the Jezdecká Basin it was 701 mm, respectively.

2006. In the next year 2006, the maximum of the snow depth and its water equivalent (SWE) in the whole area of the Jizerské hory Mountains were also measured in the middle of March (on March 13th, 2006) (Pobříslová *et al.* 2007). On March 13th, the average value of SWE was in the Uhlířská Basin 569 mm and in the Jezdecká Basin 685 mm, respectively. Figure 1 represents the map of SWE in the year 2006 without the use of the data

measured in the snow sites in CHMI experimental basins. In contrast, Figure 2 represents the map of SWE in the year 2006 with the use of the data measured in the snow sites in CHMI experimental basins. The clear difference between Figures 1 and 2 (Figure 2 is much more detailed and credible) supports the importance of measuring the snow characteristics in CHMI experimental basins for the estimation of water storage in the Jizerské hory Mts.

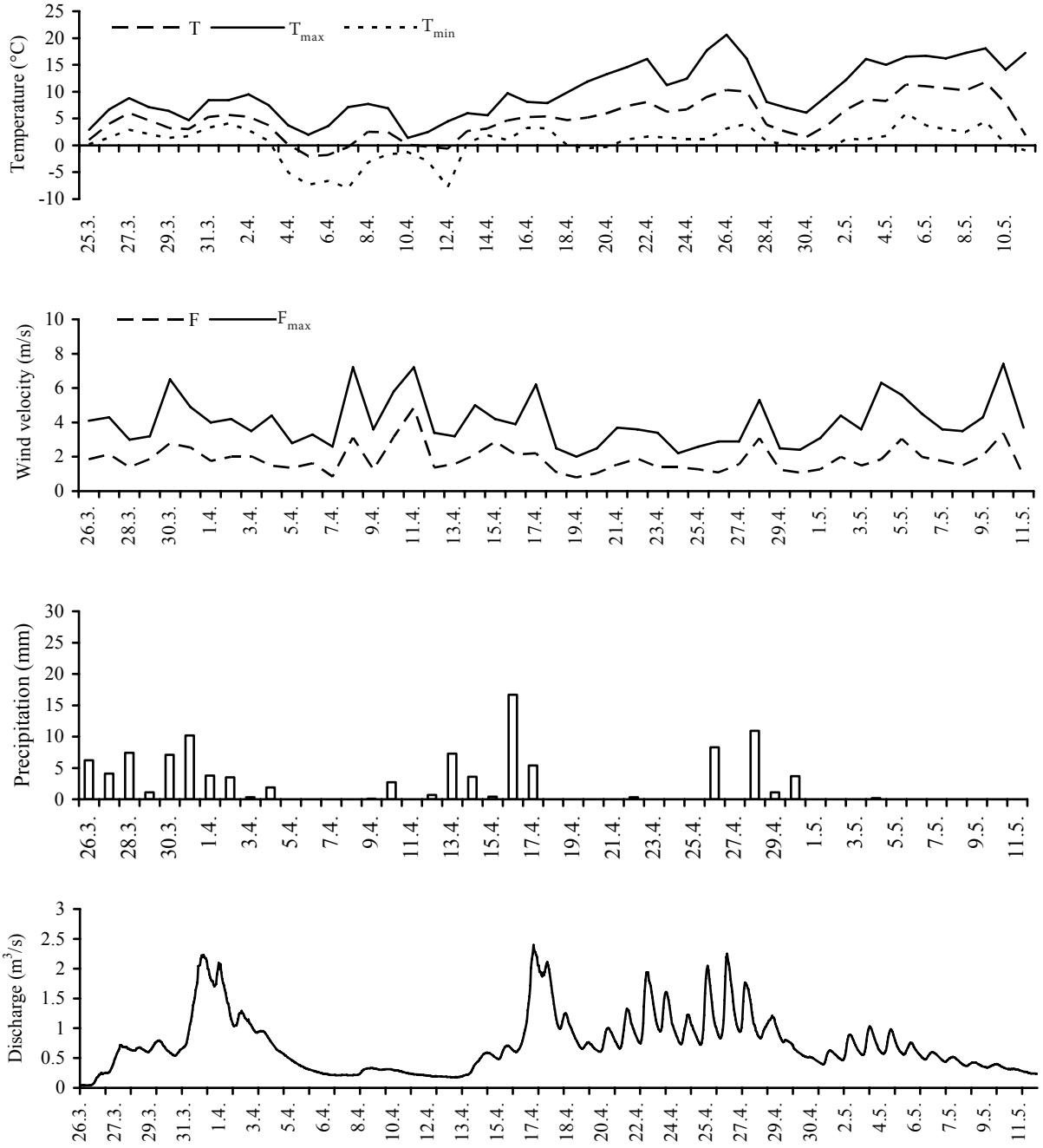

Figure 5. The Jezdecká Basin 2006 – the course of climatic characteristics and runoff during the snowmelt period 2006 (Pobříslová *et al.* 2007); the first diagram represents the course of air temperature – average, maximum, and minimum from the climatological station Desná-Souš; the second diagram represents the wind velocity – average and maximum; the third diagram represents the daily amount of precipitation, and the fourth diagram represents the runoff course

Climatic and hydrological characteristics during the snow melt period in the years 2005 and 2006

The snowmelt periods in 2005 and 2006 had the same duration but the runoff increase in 2006 started 10 days later. The basic specific runoff before the snowmelt was the same in the Uhlířská Basin 8.0 l/s/km^2 as in the Jezdecká Basin 10.3 l/s/km^2. The average snow water equivalent was lower in the Uhlířská Basin, 70% in 2005, 83% in 2006 of 701 mm, and 685 mm in the Jezdecká Basin. The precipitation in 2005 was about 50% in comparison with that in the year 2006. The total water supply in 2005 and 2006 in Uhlířská Basin was 559 and 697 mm, in Jezdecká Basin 773 and 810 mm.

The runoff course during the snowmelt period 2006 is represented on the bottom diagram of Figures 4 and 5 (Pobříslová *et al.* 2007).

Climatic characteristics during the snowmelt period 2006 are represented in Figures 4–6. The course of temperature was very similar in both basins. The average temperature was still above zero during the period, with the exception of the week from 4th to 12th of April. The average wind velocity was 1–4 m/s, with the maximum of 7 m/s. The total amount of precipitation was very similar in both basins – 128 mm in the Uhlířská Basin and 125 mm in the Jezdecká Basin.

The wind roses of the climatological stations Desná-Souš and Bedřichov-dam (they are situated near the experimental basins) are given in Figure 6. The dominant wind direction is north – 46.3% in Desná and 32.3% in Bedřichov. The south wind direction is the second most frequent – 16.4% in Desná and 17.4% in Bedřichov-dam. This fact is conditioned by the orography of the geomorphological unit of the Jizerské hory Mountains. Under the given conditions, the south wind direction can have an enormous influence on the intensity of the snowmelt.

RESULTS AND DISCUSSION

Snowmelt season 2005. Increased runoffs occurred in the experimental basins in the second half of March and at the beginning of April. The precipitation amounts were not too high, the snowmelt was significantly supported by high air temperatures with combined with strong winds in the mountains. The maximum value of the runoff was 0.9 m^3/s in the Uhlířská Basin and 3.4 m^3/s in the Jezdecká Basin.

Snowmelt season 2006. Increased runoffs at the end of March and during April were caused mainly by an intensive snowmelt with a combination of a high increase of temperature and relatively intensive precipitation. The maximum value of the runoff was 0.8 m^3/s in the Uhlířská Basin and 2.5 m^3/s in the Jezdecká Basin.

Runoff coefficients from the snowmelt periods 2005 and 2006 were compared with the Uhlířská

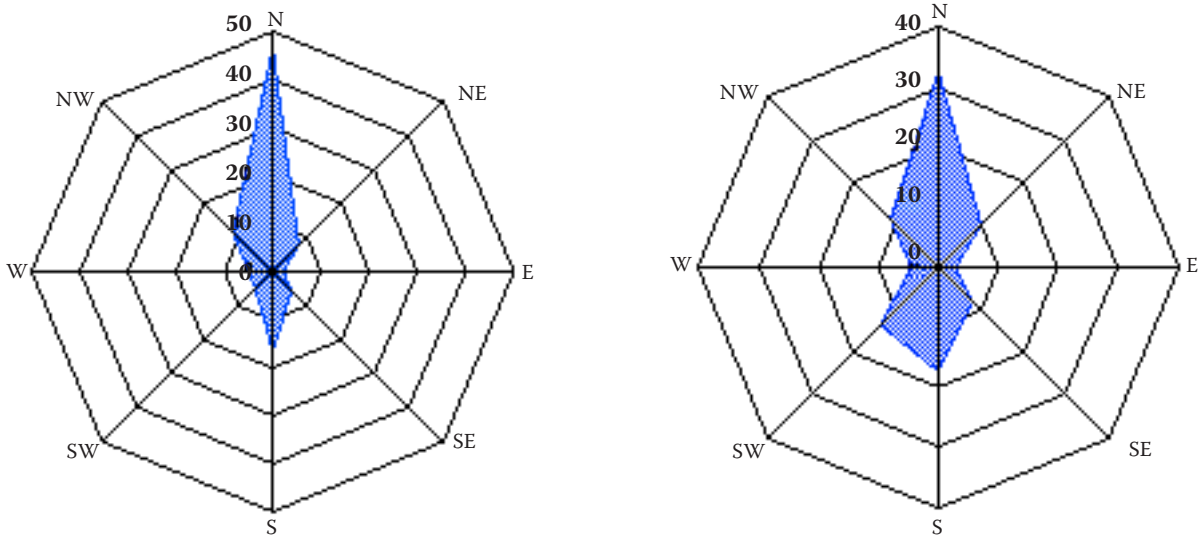

Figure 6. Wind rose – frequency of wind direction in % during the snowmelt in the year 2006 (Climatological Bank of Data 2007); the left diagram represents the data from the climatological station Desná-Souš; the right diagram those from the climatological station Bedřichov-dam

Table 1. Climatic and hydrological characteristics (SWE – snow water equivalent)

Basin	Basin area (km^2)	Runoff period	Avrage SWE (mm)	Precipitation (mm)	Total water supply (mm)	Runoff (mm)	Runoff coefficient
2005							
Uhlířská	1.87	16. 3.–1. 5.	492	66.6	558.6	355	0.636
Jezdecká	4.75		701	72.3	773.3	532	0.688
2006							
Uhlířská	1.87	26. 3.–18. 5.	569	128.0	697.0	460	0.660
Jezdecká	4.75		685	125.3	810.3	607	0.749

and the Jezdecká Basins. The runoff coefficient in the Uhlířská Basin increased in 2006 from 0.636 to 0.688 (increase by 4%) and in the Jezdecká Basin it increased in 2006 from 0.660 to 0.749 (increase by 9%). It may have been the result of a bigger volume of precipitation during the snowmelt period 2006 (see Table 1).

The differences between the water storage obtained and the total outflow during the snowmelt period could describe the differences in the hydrological response of each of the seven experimental basins, which could be useful for the hydrological forecasting, not only in this region.

Runoff modelling in the Jezdecká Experimental Basin

The Forecasting Hydrological Centre of the CHMI has used hydrological forecasting system AquaLog in the Elbe River Basin. This system is in everyday use for the Elbe River forecasts in the Forecasting Centre of CHMI. The usefulness of this procedure was proved especially during the floods from the snowmelt in last years (Řičicová *et al.* 2006a).

The values of the runoff in the Jezdecká closing profile is not operatively calculated by the

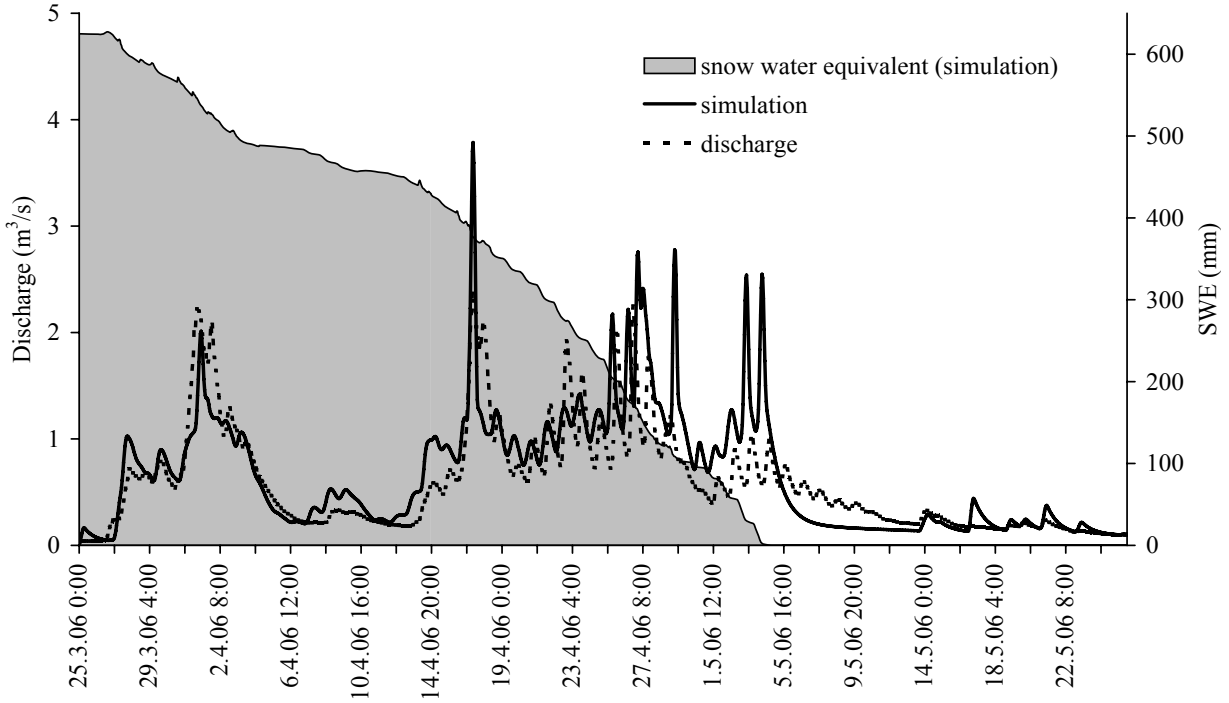

Figure 7. The Jezdecká Basin – simulation of runoff in the snowmelt period in the year 2006 (SWE – snow walue equivalent)

AquaLog system every day because this catchment is too small. Nevertheless, the data from the Jezdecká Basin with more than twenty years history of observation are very important for the model calibration.

The relatively successful simulations in the Jezdecká Basin from winter episodes in March 2005 and 2006 are conditioned especially by the extended measuring of SWE. The record-breaking values of SWE were not exceeded in the Jizerské hory Mountains, but they were unusually high. In both years, the SWE were almost the same – 500 to 700 mm.

Snow water equivalent is simulated in the AquaLog system by the subroutine SNOW17, which is based on the degree-day approach.

The result of the runoff simulation in the Jezdecká Basin is shown in Figure 7 (Řičicová *et al.* 2006a). Very characteristic are the pronounced first snowmelt event and fluctuation of water level in the dependence on the daily run of temperature and precipitation (2006). Casual precipitation and air temperature were lower at the beginning of the first wave in 2005 than in 2006, but in 2005, the peak value of discharge was higher than in 2006.

The results shown in Figure 7 prove that, with good input data, the model provides a reasonable simulation of the dynamics of accumulation and melting of the snow cover.

CONCLUSIONS

The research of the winter periods in the experimental basins began not long ago. The extended measurements of the snow characteristics in the Jizerské hory Mountains and western Giant Mountains (once per week at 28 sites) proved to be useful in the preparation of snow maps and validation of forecasting models. They allow credible calculation of the runoff coefficients in the experimental basins. Future work will be focused on a detailed analysis of the runoff coefficients during snowmelt seasons in all experimental basins. Such an analysis could help characterise the differences in the hydrological response of the individual basins.

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