Analysis of Climate Change Effects on Evapotranspiration in the Watershed Uhlířská in the Jizera Mountains

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Abstract: This study has been conducted with the aim to analyse the hydrology balance in the experimental watershed Uhlířská under the actual atmospheric conditions and expected climate changes in the upcoming years. The main accent is put on the water availability for the water root uptake by the dominant grass vegetation (*Calamagrostis villosa*). Special attention is paid to the seasonal potential evapotranspiration estimation under mountain climatic conditions. Three methods for the potential evapotranspiration quantification are analysed in order to find out the most acceptable approach for future periods for which no adequate weather data are available. The future precipitation and temperature data are simulated by the regional climate model HIRHAM which is driven by global climate model HadCM3. The data are simulated for the period from 2071 to 2100. The modelling of the soil water movement (using S1D model) is carried out on selected 18 years from the period of 1961–2005 and on selected 10 climate-change-affected years with extremely low precipitations high temperatures. The results of the scenario presented do not indicate that the climatic changes should significantly affect the hydrological balance in the studied area in terms of evapotranspiration up to the year 2100. Due to the lower seasonal precipitation and higher air the temperature, was increased in the results of simulations under the defined approach, however, the local vegetation cover did not suffer from insufficient water supply. These considerations are close to the simulation models used.

Keywords: air temperature; climate change; climate models; potential evapotranspiration; precipitation; soil water movement; simulated actual evapotranspiration

With respect to the location of the Czech Republic in the mild climatic zone, the change of the climate is mainly expected to affect the air temperature and precipitation intensity and distribution. The expected climate change might evoke changes in the areas of water resources, agriculture, forestry, and public health. From the hydrological point of view, the climate change might initiate chain reactions of the regional characteristics (i.e. changes of groundwater levels, vegetation cover, and surface runoff).

The climatic conditions on the Earth have ever been changing. The climatic changes are caused by internal processes, external processes (e.g. variations in the sunlight intensity) or, since recently, by anthropogenic activities.

The climate system is a complicated non-linear system where all processes are connected with irreversible and difficult relationships (Pretel & Vácha 2003). The climate models aim at mathematical description of such a system. Nevertheless, this description can supply approximate results. Some climate models can simulate both the future and present climatic data in the dependence on the location. Good knowledge of the past climate development, present situation, and expected future are used as the input data for global and regional climate models. The climate models are then used

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Table 1. Selected years for hydrological balance simulation (1961–2100)

Climatic data from station Uhlířská							
1998	1999	2000	2002	2003	2005	2006	2007
Climatic data from station Bedřichov							
1965	1976	1982	1983	1988	1992	1994	1995
2002	2003						
Simulated and modified climatic data for the station Bedřichov							
2073	2078	2080	2091	2093	2094	2095	2097
2099	2100						

for the evaluation of the global climate change. Some fluctuations in the long-term averages of climatic characteristics have been already observed, being caused by either anthropogenic or natural effects.

We present the results from two climate models aimed at analysing the hydrological regime in the experimental watershed Uhlířská, taking into consideration the actual atmospheric conditions and the expected conditions as affected by the climate change. The main objective of this study is to show the impacts of the climate change on the local vegetation cover, in terms of sufficient water supply. The demand for water for evapotranspiration is evaluated using a soil water flow simulation model S1D (Vogel *et al.* 1993, 2004). Sufficient the water for the water root uptake is determined by the evaluation of the plant water stress function. The simulation of the soil water movement is based on the data coming from 1961–2007 and on the selected ten climate-change-affected years with extremely low precipitations and high temperatures (Table 1). All scenarios were simulated during the vegetation season only.

MATERIAL

Experimental watershed Uhlířská

The experimental watershed Uhlířská locality Tomšovka is located in the Jizera Mountains in the Czech Republic (with coordinates 50°49'N, 15°08'E). The study area is situated at the average altitude of 822 m a.s.l. It is expected that the variations in long-term climatic averages could negatively affect the hydrological balance below the watershed, primarily in terms of floods or droughts. The mountain watershed selected belongs to very humid areas with the annual average precipitation above 1200 mm. The area (deforested in early 80's) is presently covered with *Calamagrostis villosa* that is the dominant grass cover vegetation. The watershed area has been continuously covered with *Quercus*, *Larix decidua* Mill. and *Sorbus* (Šanda *et al.* 2004). *Calamagrostis villosa* was selected for the evaluation of the actual evapotranspiration in this study. This type of grass is recognised as weather – resistant vegetation, wilting points for

Table 2. Soil hydraulic characteristics (Dohnal *et al.* 2006)

Layer	Depth (cm)	θ_r (–)	θ_s (–)	α (cm^{-1})	n (–)	K_s (cm/day)	h_s (cm)
1	0–8	0.2	0.69	0.05	2.0	1700	0
2	8–20	0.2	0.67	0.05	1.5	200	–0.69
3	20–70	0.2	0.61	0.02	1.2	50	–1.48
4	70–75	0.2	0.51	0.02	1.2	4	–1.88

θ_r, θ_s – residual and saturated soil water contents; α, n – van Genuchten's empirical parameters; K_s – saturated hydraulic conductivity; h_s – air entra value

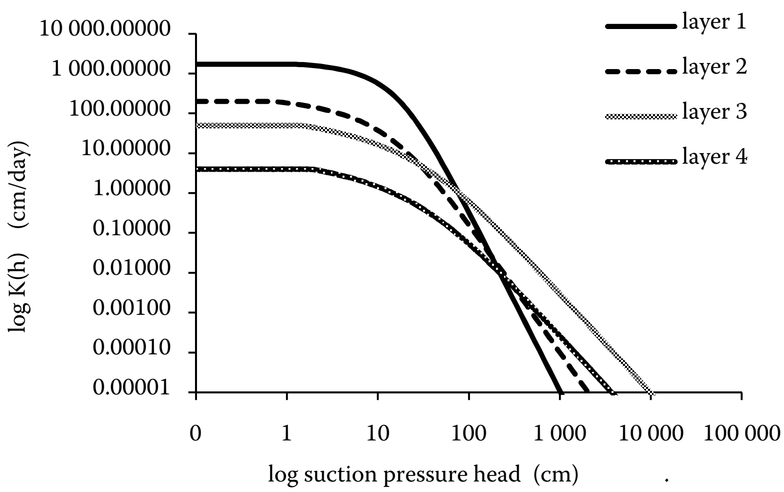

Figure 1. Retention curves of soil profile layers

such type of grass are assumed between soil water pressure heads –100 and –150 m.

The typical soil profile on the hillslope consisting of four layers is 75 cm deep. First two layers up to –20 cm, representing the root zone of *Calamagrostis villosa*, have high hydraulic conductivities and get dry during the periods with low precipitation. The retention curves of the soil layers are presented in Figure 1. The soil layers follow the bottom of the soil profile. At 75 cm are disintegrating crystalline rocks of a very low hydraulic conductivity (Figure 2). Hypodermical flow was detected along the bottom of the fourth soil layer of the soil profile. The soil hydraulic characteristics are presented in Table 2.

Climatic data

The hydrological balance analyses require basic climatic data that is precipitation and air temperature. The available climatic data of the studied watershed Uhlířská are limited to the period of 1997–2007. Since a long-term database of the climatic data is required for the analysis of the climate change effect, the climatic data from the station Bedřichov are used. The Bedřichov weather station is located 2 km from the experimental site at approximately the same altitude (777 m a.s.l.).

The precipitation and temperature data for the period of 2071–2100 were obtained from the PRUDENCE project. Within the frame of this project, managed by the Danish Meteorological Institute, climatic data for the present and upcoming years were simulated. The local scale climate change was simulated by the respected regional climate model HIRHAM (Christensen *et al.* 1996) driven by the global model HADCM3 (Kliková 2008).

Four SREC different scenarios are given for different greenhouse gas emission predictions. The results of the PRUDENCE project follow SREC A2 scenario (Nakićenović *et al.* 2000) while the regional oriented economy growth is expected and the local tradition and identity keeping will play a dominant role. The PRUDENCE project results were the first ones using climate models of a very high

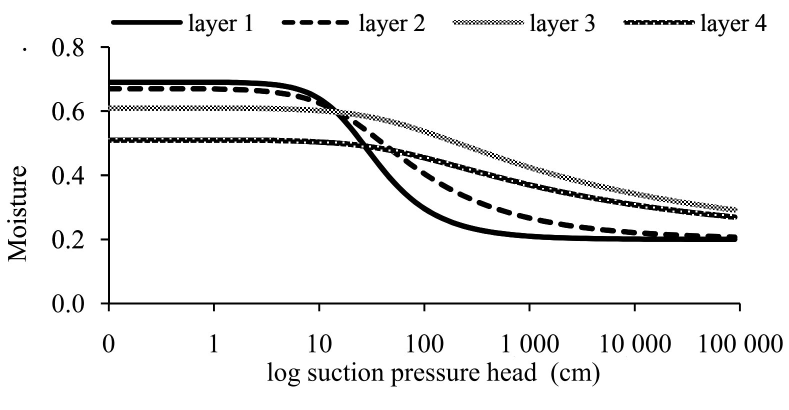

Figure 2. Hydraulic conductivity functions

resolution on the continental scale that were used for the comparison and evaluation of possible climate change effects (Christensen *et al.* 1996).

The results of the climate change simulations in terms of precipitations and air temperatures are presented at a dense grid over Europe. A node closest to the studied watershed located at a similar altitude was chosen for this study. The selected grid point has coordinates 50°43'N, 15°42'E and it is located at 849 m a.s.l. Monthly averages of the climatic characteristics which are usually used were not detailed enough for this study. The hydrological balance simulations during the vegetation seasons are carried out in daily steps; daily-simulated climatic data (air temperature and precipitation) are then required. The delta approach for the daily data has been applied, the daily differences of temperatures and daily fractions of precipitation of the measured and simulated present data (1961–1990) have been used. This approach is used to adapt the simulated data of the grid point for the local climatic conditions of the station Bedřichov.

The daily-simulated precipitation values from the PRUDENCE project of the period 1961–1990 are significantly overestimated, which means that we can assume that the data in the period of 2071–2100 will be overestimated as well (Kliková 2008). In addition, the selection of the grid point and climate models themselves can cause differences between the measured and the simulated present climatic data. Table 3 shows average climatic characteristics, both measured and simulated.

The simulated temperatures and precipitations were used for a comparative study of the potential evapotranspiration and they were used as the inputs for the soil water flow model S1D. The modelling of the soil water movement was carried out on the selected years with extremely low precipitations and high temperatures during the vegetation season (Table 1).

METHODS

Estimation of potential evapotranspiration

The estimation of the potential evapotranspiration (ETp) of *Calamagrostis villosa* was found as the crucial issue of this study. Several methods can be used for the estimation of ETp in the watershed studied. In this study, the potential evapotranspiration was estimated by means of three methods applied in the years 2003 and 2004 when the required climatic data were directly measured in the watershed Uhlířská:

Modified Penman-Monteith method (FAO, Allen *et al.* 1998)

Hargreaves method

Penman-Monteith method

Table 3. Average climatic data, measured and simulated

	Measured 1961–1990 (CHMI) Bedřichov	Simulated for 1961–1990 DMI F25	Simulated for 2071–2100 DMI S25	Simulated for 2071–2100 DMI S25, adjusted Bedřichov
		grid point 50°43'N, 15°42'E, 849 m a.s.l.		
Precipitation (mm)				
Annual precipitation	1233	1877	1819	1191
Aeasonal precipitation	684	992	891	607
Air temperature (°C)				
Annual air temperature	4.6	4.5	8.1	8.1
Seasonal air temperature	10.6	10.3	12.9	14.2
Maximal air temperature (°C)				
Annual max. air temperature	8.7	7.3	11.0	12.4
Seasonal max. air temperature	15.5	14.2	17.3	19.3
Minimal air temperature (°C)				
Average min. air temperature	0.8	1.2	5.0	4.7
Seasonal min. air temperature	6.5	7	10.3	9.8

The method FAO Penman-Monteith is known as one of the most convenient methods for ETp estimation. In the case of absence of the required climatic data, it offers other approaches to obtain them. The estimation of the potential evapotranspiration by the method FAO Penman-Monteith, however, strongly depends on the vegetation growth data. A detailed study on the vegetation growth of the local vegetation cover (*Calamagrostis villosa*) has not been performed yet.

For the 2003 and 2004 ETp estimation, when the required data had been measured, the Hargreaves method was used although this method is considered only as alternative and supplemental. Under a high relative humidity, the selected Hargreaves method has a tendency to overestimate the reference evapotranspiration (ETo) which makes the base for the particular plant potential evapotranspiration (Allen *et al.* 1998). For this reason, the Hargreaves method was selected as the most appropriate for the estimation of ETp in the studied watershed within the period 2071–2100. The method was also used for ETp estimation during the period 1961–2007.

Regarding the empirical character of the Hargreaves equation, it is recommended to verify all constants for each region by the Penman-Monteith method using the measured climatic data from the weather station (Allen *et al.* 1998). In the watershed Uhlířská it was done by Herza (2005), the verified Hargreaves equation being in the form

$$\mathrm{ETo} = 0.003(T_{average} + 3)\,(T_{max} - T_{min})^{0.5} R_a \times 0.408 \quad (1)$$

where:
$T_{average}$ – average daily temperature (°C)
T_{max} – maximum daily temperature (°C)
T_{min} – minimum daily temperature (°C)
R_a – extraterrestrial radiation received at the top of the earth atmosphere on a horizontal surface (mm/day)

The potential evapotranspiration can be expressed as reference (potential) evapotranspiration (ETo), when the potential evapotranspiration is evaluated for the reference vegetation using the vegetation factor $K(T)$ which is specific for each type of vegetation

$$\mathrm{ETp} = \mathrm{ETo} \times K(T) \quad (2)$$

where:
$K(T)$ – vegetation factor

The vegetation factor is usually determined as a fraction of ETp/ETo (Allen *et al.* 1998).

The estimation of the vegetation factor requires detailed knowledge of the growth of *Calamagrostis villosa* during the vegetation season. Based on the assumption that the grass is stressed by low temperatures (Wright & Harding 1993), the potential evapotranspiration equals zero below 5°C. Above 10°C, the potential evapotranspiration is assumed to be equal to the reference evapotranspiration. Within the interval of 5–10°C, the potential evapotranspiration is modified according to Herza (2005).

Simulation of hydrological balance

For modelling the water flow in the soil profile under specific climatic conditions, the deterministic model S1D is used (Vogel *et al.* 1993, 2004). The selected model provides the required answers about the potential climate effects on the hydrological balance in the watershed Uhlířská. The model S1D has been used to simulate the water movement in variably saturated media. In the code the Galerkin finite element method is applied to solve Richard's equation numerically. This equation is based on the assumption of one-dimensional isothermal flow in variably saturated porous media. The water flow is described by one-dimension equation

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x}\left[\mathrm{K}\left(\frac{\partial h}{\partial x} + \cos\alpha\right)\right] - S \quad (3)$$

where:
θ – volumetric water content (L^3/L^3)
h – pressure head (L)
S – sink term (T^{-1})
x – spatial coordinate (L)
t – time (T)
$\cos\alpha$ – cosine of the angle between the flow direction and the vertical axis (for the vertical flow $\cos\alpha = 1$)
K – unsaturated hydraulic conductivity (L/T)

The sink term S represents the volume of water removed per unit of time from a unit volume of soil due to the plant root water uptake. The sink term S was defined by Feddes *et al.* (1978) as

$$S(h) = a(h)S_p \quad (4)$$

where:
$a(h)$ – prescribed dimensionless function of h ($0 \leq a(h) \leq 1$)
S_p – potential water uptake in the root zone (T^{-1})

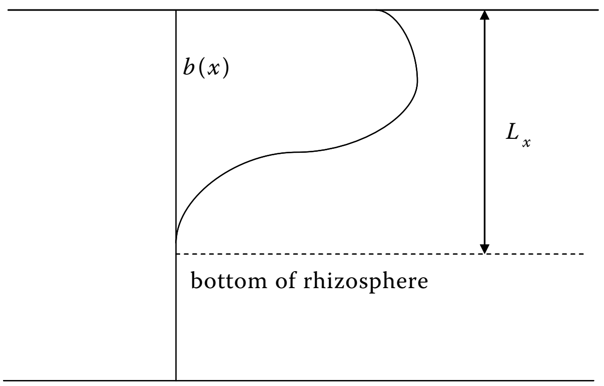

Figure 3. Distribution function of potential root water uptake $b(x)$

S_p is equal to the soil water uptake during the period of no water stress when $a(h) = 1$.

The scheme of the spatial distribution function of the potential root water uptake $b(x)$ is presented in Figure 3. The water stress function recommended by Feddes *et al.* (1978) is used in the numerical model S1D (Figure 4). Optimal soil water conditions for the plant transpiration are defined between h_3 and h_2 values of the soil water pressure head. The value h_3 depends on the intensity of the potential transpiration. The wilting point is given at h_4. Within the interval (h_2, h_1), transpiration is reduced due to the reduced amount of aeration in the root zone. In this study, the potential root water uptake in the root zone is given by the potential evapotranspiration of *Calamagrostis villosa*.

The simulations were performed in vertical direction of the soil profile. The soil profile stratification (Figure 1, Table 2) reflects the average soil conditions in the area studied. The free drainage boundary condition was set at the depth of 75 cm. The upper soil profile atmospheric boundary was prescribed for the simulation of precipitation infiltration and potential evapotranspiration (Vogel *et al.* 2004). Since all soil profile layers have rather a high hydraulic conductivity, all rainfall is infiltrated in all scenarios. The growth conditions and details of the dominant cover vegetation *Calamagrostis villosa* have not been studied yet. The grass is a very resistant cover vegetation. The root zone reaches up to 20 cm. The wilting points were alternatively set at –80 and –120 m to simulate the most critical cases (Dohnal *et al.* 2006).

The years with low precipitations and high temperatures in the watershed Uhlířská were selected for the simulations. The effects of climate change on vegetation were estimated by evaluating the calculated potential evapotranspiration and the simulated actual evapotranspiration in daily steps. Attention was paid to the water stress periods of *Calamagrostis villosa* evaluation.

RESULTS AND DISCUSSION

The hydrological balance simulations were carried out for 28 selected years and with respect to the vegetation growth in the locality Tomšovka. The results are divided into three parts based on the climatic data availability. The evaluation of the water stress period during the vegetation seasons was performed by comparing the calculated

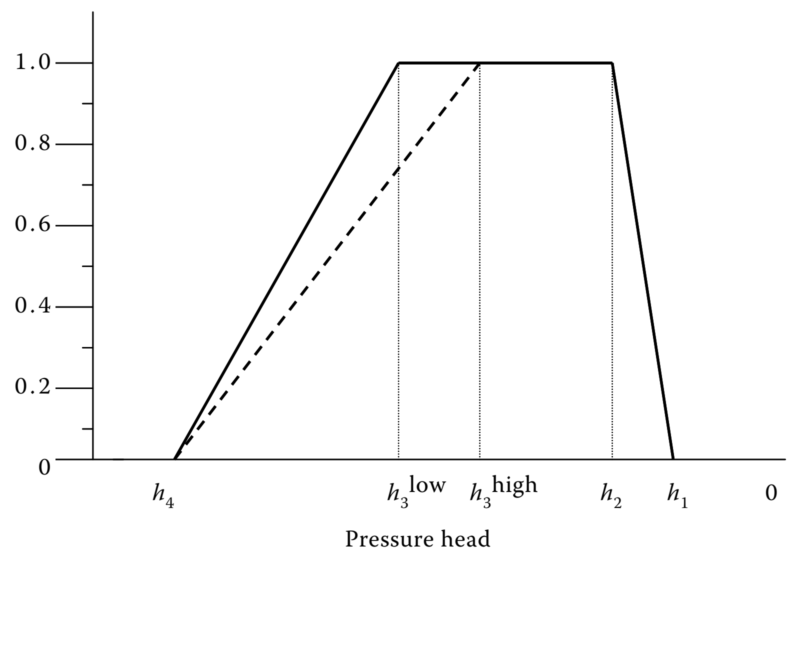

Figure 4. Plant water stress function $a(h)$ as suggested by Feddes *et al.* (1978)

Table 4. Water stress evaluation for selected years

	Year	Difference of ETp and simulations ETa during season (mm)	Wilting point (m)	Dry period	Period of water stress	No. of days	Difference between ETp and simulations ETa in dry periods (mm)	Min. suction pressure head (cm)
Uhlířská – measured data	1999	11	–120	I	August 8	1	0.31	–2.08E + 06
	2000	1	–120	I	no water stress			–3.27E + 02
	2002	1	–120	I	no water stress			–4.04E + 02
	2003	7	–120	I	July 16	1	0.72	–1.57E + 12
	2006	17	–80	I	July 20–27	8	11.62	–1.31E + 27
Bedřichov – measured data	1976	12	–120	I	July 2–8	7	4.39	–4.03E + 05
	1982	8	–120	I	no water stress			0.00E + 00
	1982	8	–120	II	August 2–5	4	1.81	–1.57E + 12
	1982	8	–120	III	no water stress			0.00E + 00
	1983	1	–120	I	July 28	1	0.43	–2.49E + 08
	1992	3	–120	I	no water stress			–1.62E + 03
	1994	41	–80	I	July 22–August 6	16	32.76	–1.91E + 09
	1995	1	–120	I	August 5–6	2	0.71	–8.30E + 04
	2002	4	–120	I	no water stress			–1.15E + 04
	2003	7	–120	I	no water stress			–5.75E + 03
	2003	7	–80	I	no water stress			–2.38E + 03
Bedřichov – simulated data	2080	2	–120	I	August 4	1	0.57	–1.59E + 03
	2091	21	–120	I	no water stress			–3.91E + 03
	2093	9	–120	I	no water stress			–1.93E + 03
	2094	10	–120	I	no water stress			–2.16E + 03
	2095	39	–80	I	July 27–August 1	6	6.97	–1.22E + 05
	2095	39	–80	II	August 10	1	0.21	–9.62E + 03
	2099	3	–120	I	no water stress			–1.13E + 03
	2100	30	–120	I	September 1–3	3	2.78	–8.51E + 11
	2100	30	–120	II	September 16–20	5	7.94	–6.17E + 04

potential evapotranspiration and the simulated actual evapotranspiration. When no difference between the calculated potential evapotranspiration and the simulated actual evapotranspiration was found, it could be assumed that there was a sufficient supply of water for transpiration. When a difference was found between these two values, it was considered that the local vegetation was facing water stress, and such periods were analysed in detail.

The first two parts of simulations were performed for the period with the measured climatic data from the Uhlířská weather station and Bedřichov station, respectively. In the third part, simulations for selected years from the period 2071–2100 were performed. In this case, the simulated climatic data from the climate models HIRHAM/HadCM3 were used. The overall results are presented in Table 4.

The first part includes eight simulations of hydrological balance with selected years from the period 1997–2007 (Table 1). During three years (1998, 2005 and 2007), the local vegetation was not exposed to water stress, the cumulative potential evapotranspiration was equal to the cumulative simulated actual evapotranspiration.

The cumulative actual evapotranspiration was lower than the potential evapotranspiration in the years 2000 and 2002. Daily values of ETp were calculated, nevertheless, the root pressure head did not surpass the suction pressure head equalled to the water stress values (–120 m). Only one-day exposure to water stress was observed during the years 1999 and 2003. Such a short period did not have a negative effect on the local vegetation growth. The eight-day period in the year 2006 was the longest dry period of this first part of the simulations. The difference between the cumulative ETp and the cumulative simulated ETa was 11.62 mm in one day. The lowest suction pressure head from all simulations was found in that year. Nevertheless, during the observations in the location, no negative visual effects on the vital functions of the grass were noticed during the simulated years in the present period.

The second part includes 10 hydrological balance simulations based on the climatic data measured at the Station Bedřichov in the period of 1961–2005. During the years 1965 and 1988, no water stress periods were found in the results, the cumulative simulated ETa was equal to the cumulative ETp. In 1982, 1992, 2002, and 2003, water stress was not observed although the cumulative simulated ETa was lower than the cumulative ETp. The very low precipitations during two vegetation seasons (346 mm in 1982, 391 mm in 2003) did not expose the local grass to water stress. Short-term periods (1–4 days) of water stress were identified during years 1982, 1983, and 1995. As little as 5.5 mm of rainfall in the period of June 17–July 17 1976 caused a seven-day water stress period. The longest period of water stress from the whole studied period of 1961–2100 (that means including the generated climatic data period) was observed in 1994. The 16-day period of water stress period was dry due to very low precipitation (544 mm du-ring vegetation season, 27 mm in July) and above – average maximal daily air temperature (30°C in June, 33°C in July and 32°C in August).

The third part includes the simulations of 10 selected years from the period of 2071–2100 for which the simulated climatic data from the climate models HIRHAM/HadCM3 were used. In this selection, dry periods were expected based on the analysis of the simulated precipitation and air temperature during the vegetation seasons. However, these expectations were not confirmed. During the years 2073, 2078, and 2097 (out of the selected 10), the local vegetation should be continuously supplied with water. Lower precipitations were simulated during the vegetation seasons of 2091, 2093, 2094, and 2099, but no water stress for the plant under study was identified. Short-term periods (1 to 5 days) of water stress were recognised in the years 2080 and 2100. The longest period of 6 days (July 27–August 1) of water stress was observed in 2095. The soil water stress was a result of low seasonal precipitation (517 mm), the long-term average of precipitation (2071–2100) was simulated at 607 mm during the vegetation season. Very high air temperature (28.5°C) was simulated in August; this month exhibited the highest monthly mean air temperature during 2071–2100.

From the evaluation of the simulations of hydrological balance, an increase of simulated ETa was evident. From Table 5, an increase is obvious of the simulated ETa during the period 2071–2100. The simulated ETa was in the interval 1.91–2.36 mm/day, most of the values being above 2 mm/day.

The results of the hydrological balance simulated using the selected model S1D indicate that the area studied should not suffer from water deficit. The short-term soil water stress periods were observed during present years (1961–2005) and during the period of 2071–2100. High annual rainfall, low temperatures, and a high humidity reduce evapotranspiration at the altitude of the experimental mountain area. The increased evapotranspiration in the period of 2071–2100 is caused by the decreased annual rainfall and the increased air temperature (see Table 3). The lower precipitation results in a reduced amount of infiltrated water.

Considering the experience from the local observations, *Calamagrostis villosa* was not negatively affected during the periods low in precipitation. The same may be expected in the future. Based on the simulation models selected, the local vegeta-

Table 5. Results of hydrological balance simulations, overview of simulated ETa and ETp

Location/year	Cumulative ETp	Cumulative simulated ETa	Difference of cumulative ETp and cumulative simulated ETa	Max ETp	Average ETp	Average ETa
	(mm)			(mm/day)		
Uhlířská						
1998	307	307	0	5.08	1.68	1.68
1999	333	332	1	4.61	1.82	1.81
2000	328	327	1	5.42	1.80	1.80
2002	371	370	1	5.08	2.03	2.02
2003	408	401	7	5.10	2.36	2.31
2005	298	298	0	4.86	1.67	1.65
2006	331	314	17	5.25	1.91	1.82
2007	322	322	0	5.06	1.75	1.75
Bedřichov						
1965	268	268	0	4.90	1.45	1.45
1976	295	283	12	4.77	1.60	1.54
1982	337	329	8	4.99	1.83	1.79
1983	324	323	1	5.18	1.77	1.75
1988	317	317	0	4.88	1.74	1.74
1992	265	262	3	4.58	1.99	1.98
1994	342	301	41	5.28	1.86	1.65
1995	323	322	1	4.86	1.76	1.75
2002	321	317	4	4.94	1.76	1.74
2003	330	323	7	4.80	1.80	1.77
Bedřichov						
2073	400	400	0	4.05	2.19	2.19
2078	352	352	0	4.53	1.93	1.91
2080	387	385	2	4.65	2.11	2.10
2091	418	397	21	5.08	2.27	2.16
2093	441	432	9	5.86	2.40	2.36
2094	415	405	10	4.67	2.27	2.22
2095	429	390	39	5.29	2.33	2.13
2097	426	426	0	4.74	2.33	2.33
2099	418	415	3	4.84	2.28	2.27
2100	450	420	30	4.75	2.45	2.29

tion cover should not be affected by the climate change in the terms of growth.

CONCLUSION

The climatic conditions on the Earth have been changing continuously. The main aim of the study was to evaluate potential effects of climate change on the hydrological balance in the watershed Uhlířská in the Jizera Mountains during the period 2071–2100. The hydrological balance simulations were carried out by the deterministic model S1D (Vogel *et al.* 2004) with respect to the expected changes of precipitation and air temperature patterns in near future. The simulated climatic data for this study were calculated by the climate models HIRHAM/HadCM3 (run under the PRUDENCE project).

The simulated actual evapotranspiration values of the current grass plantation (*Calamagrostis villosa*) during the vegetation seasons were assessed. The evaluated results of the simulated actual evapotranspiration and potential evapotranspiration of particular vegetation seasons up to 2100 show that significant changes of the hydrological balance are not expected (see chapter Results and Discussion).

From a long-term perspective, the local vegetation cover should not suffer from insufficient water supply. Some short-term periods (couple of days) when the vegetation is facing water stress are observed for the present years, but for the upcoming years (2071–2100) as well. From the local observations, such short episodes should not have any significant effect on the *Calamagrostis villosa* growth due to its high water resistance.

The climate change is a heavily discussed topic. There are observations proving its progress as accelerating. Generally, we talk about global changes, although the particular effects will take place mainly on the regional levels. Based on the results from the watershed Uhlířská, the changes of the hydrological balance in the areas at similar altitudes in Central Europe will not be necessarily significant. Therefore, no considerable effects on the hydrological cycle or dryness of the soil profile can be expected in the lowlands unless the locality itself is in extreme climatic conditions. These considerations are close to the simulation models used in the presented study.

The results from the model can be considered as one of the potential ways of the hydrological balance evaluation. Since the simulated climate data from the PRUDENCE project follow the SREC A2 scenario, the results are only one example of the possible effects of climate change on the local hydrological balance. The same flexible approach for the potential climate change effect on hydrological balance can be used also in other localities and areas (e.g. evaluation of climate change effects on agriculture crops).

References

Allen R.G., Pereira L.S., Reas D., Smith M. (1998): Crop evapotranspiration (Guidelines for computing crop water requirements). FAO irrigation and drainage paper 56, Food and Agriculture Organization of the United States, Rome.

Christensen J.H., Christensen O.B., Lopez P., Van Meijgaard E., Botzet M. (1996): The HIRHAM4 Regional Atmospheric Climate Model. Scientific Report 96-4. DMI, Copenhagen.

Dohnal M., Dušek J., Vogel T., Herza J., Tachecí P. (2006): Analysis of soil water response to grass transpiration. Soil and Water Research, **1**: 85–98.

Feddes R.A., Kowalik P.J., Zaradny H. (1978): Simulation of Field Water Use and Crop Yield. Simulation Monographs. Pudoc, Wageningen.

Herza J. (2005): Estimation of evapotranspiration in the mountain catchment, Jizera Mountains, CR. [MSc. Thesis.] Cranfield University, Silsoe, UK.

Kliková B. (2008): Analysis of uncertainty in regional climate models outputs. [MSc. Thesis.] Department of Meteorology and Environment Protection, Charles University, Prague.

Nakićenović N., Alcamo J., Davis G., De Vries B., Fenhann J., Gaffin S., Gregory K., Grobler A., Yong Jung T., Kram T., La Rovere E.L., Michaelis L., Mori S., Morita T., Pepper W., Pitcher H., Price L., Riahi K., Roehrl A., Rogner H., Sankovski A., Schlesinger M., Shukla P., Smith S., Swart R., Van Rooijen S., Victor N., Dadi Z. (2000): Special Report on Emissions Scenarios: A Special Report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

Pretel J., Vácha D. (2003): Internet web page focusing on climate change preparation. Czech Hydrometeorological Institute, Prague. Available at http://www.chmi.cz/nkp/nkp.html

Šanda M., Vogel T., Císlerová M. (2004): Hydrograph formation in the hillslope transect. In: Proc. Conf.

Progress in Surface and Subsurface Water Studies at the Plot and Small Basic Scale. Turin.
Vogel T., Zhang R., Van Genuchten M.T. (1993): The S1D Software Package for Simulating Water, Solute and Heat Movement in Variably- Saturated Porous Media, Version 1.0. Research Report No. 132, U.S. Salinity Laboratory, ARS, USDA, Riverside.
Vogel T., Dohnal M., Dušek J. (2004): Bench Scale Modelling Approaches. Eberhard Karls Universität Tübingen, C1.1, Tübingen.
Wright I.J., Harding R.J. (1993): Evaporation from natural mountain grassland. Journal of Hydrology, **145**: 267–283.

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