Spatial distribution of HBV-ETH model

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ABSTRACT: The original HBV model is a conceptual, rainfall-runoff, semi-distributed model for daily runoff simulation. The advantage of this model is the minimum input data requirement. Therefore are HBV-based models often applied in mountainous regions with sparse-dense meteorological network with relative good results. HBV-ETH variant was developed for the purpose of rainfall-runoff simulation in the alpine catchments, whereas the snowmelt algorithm was emphasized. The snowmelt rates are estimated on the base of temperature-index method. The aim of the study is to create a model, based on HBV-ETH for the purpose of snow-cover modelling in mountainous regions of Czech Republic
The primary extension is the spatial distribution. Including DEM and consequential terrain properties analysis, like slope and aspect leads to more accurately snowmelt modelling.
Snowmelt module, which works on the basis of temperature-index method, is extended for simplified energy-balance principle, where the terms of energy-balance equation are derived on the basis of minimal meteorological inputs.

KEYWORDS: Snow cover, snowmelt modelling, spatial distribution

1 INTRODUCTION

Over the past few decades, hydrological research has been focusing on modelling of the impact of climate and landscape changes on the hydrological cycle. The outcomes of such studies may be applied for instance in drinking water management, agriculture (Adams et al., 1995), water power industry or ecology (Corn, 2003). A great deal of attention has been devoted to mountain catchments where more substantial changes are likely to occur, as there is snow cover present and the catchments are very quick to respond to temperature change (Giese and Moßig, 2004).

The ability to apply a hydrological model to a mountain catchment with significant snow cover depends on the quality of snowmelt modelling (Valeo and Ho, 2004). At present, there are already a number of models available which incorporate snowmelt (USACE 1960, Bergström, 1976, Leavesley et al. 1983, Jordan 1990, Martinec et al. 2008).

In areas with sparse measuring network where it is not possible to obtain sufficient data to determine all the components of the energy balance, it is often temperature-index models which are used (Hock, 2003). One of these models is the HBV-ETH model (Renner and Braun 1990), often used in many studies (i.e. Hagg et al., 2007).

Walter et al. (2005) described snowmelt computation via process-based method, using energy components estimated from measured daily minimum and maximum temperature, i.e. using only similar data required for temperature-index models.

The purpose of this study is to upgrade the HBV-ETH model to an spatial distributed version and add new snowmelt routine method (according to Walter et al., 2005) to the existing snowmelt module and compare these two principles. In this short paper are presented the first results.

2 METHODS

Model HBV-ETH was developed at ETH Zürich for the purpose of modelling rainfall-runoff processes in the mountainous catchments (Renner and Braun, 1990). In 1999 was developed current version, HBV3-ETH9, which is used for this study (KfG, 1999).

Spatial distribution of model is realized especially because of the computation of potential solar irradiation. Terrain is divided into grid and the computation runs in every one cell of this grid. The grid resolution defines the resolution of computation. Figure 1 shows the difference between the original HBV-ETH and the new, spatially distributed version.

Beside the temperature-index method, the snowmelt rate is estimated by solving equation (Walter et al., 2005):

$$\lambda\Delta SWE=S+L_a-L_t+H+E+G+P-SWE(C\Delta T_s) \quad (1)$$

where λ is the latent heat of fusion = 3,34 x 10^5 kJ m^{-3}, ∆SWE is the change in the snowpack's water equivalent (m), S is the net incident solar radiation (kJ m^{-2}), L_a is the atmospheric longwave radiation (kJ m^{-2}), L_t is the terrestrial longwave radiation (kJ m^{-2}), H is the sensible heat exchange (kJ m^{-2}), E is the energy flux associated with the latent heats of vaporization and condensation at the surface (kJ m^{-2}), G is

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ground heat conduction to the bottom of the snowpack (kJ m^{-2}), P is heat added by rainfall (kJ m^{-2}), SWE($C\Delta T_S$), is the change of snowpack heat storage (kJ m^{-2}).

Members of this equation are estimated using only the day of the year, daily maximum and minimum temperature, and geographic latitude, all of which are readily available throughout much of the world.

Computation of potential solar irradiation for sloping surfaces is based on theory given by Lee (1963).

For every catchment was made 20 simulation - 10 simulation with calibrated temperature-index method and 10 simulation with simplified energy balance method. The calibration and validation periods are:

Calibration period: 1.11.2000 - 31.10.2005
Validation period: 1.11.2005 - 31.10.2010

Accuracy of each simulation is defined by Nash-Sutcliffe coefficient (Nash and Sutcliffe, 1970). To evaluate the differences between the simulations, the obtained values of Nash-Sutcliffe coefficient were compared by an unpaired two-tailed t-test (Becker et al., 1988).

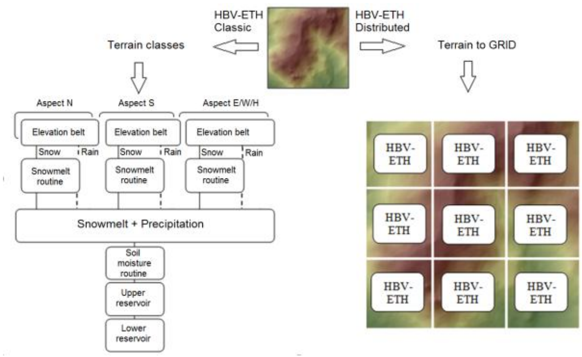

Figure 1. Principle of spatial distribution of the HBV-ETH model.

3 STUDY SITE

Both variants of snowmelt routine were tested on small experimental catchments (Cerna Nisa, Kamenice, Cerna Desna) in Jizera Mountains, in the north part of Czech Republic (figure 2). The average annual precipitation in the region ranges between 1300–1800 mm, average annual temperature is 4,4 °C at an altitude of 750 m. a.s.l. Between the years 1983 and 1993 was about 60 - 80% of the area deforested because of the acid rains (Kulasová et al, 2006).

Basic description of the catchments:

	Area [km^2]	Discharge [m^3s^{-1}]
Cerna Nisa:	1,87	0,055
Cerna Desna:	4,75	0,196
Kamenice:	6,62	0,252

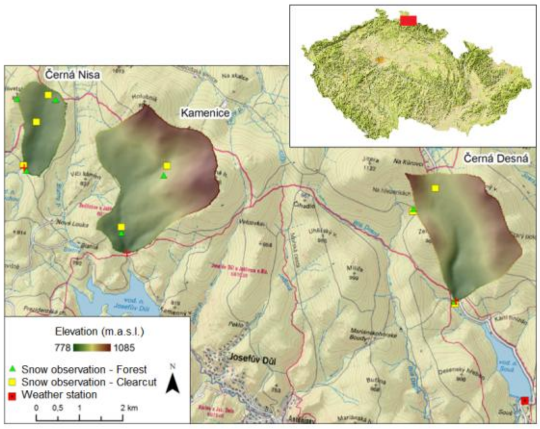

Figure 2. Overview of the study site showing the locations relative to the Czech Republic.

4 RESULTS

Distribution of Nash-Sutcliffe coefficient values during period of calibration is shown in figure 3. In figure 4 is the distribution from the period of validation. Mean values of Nash-Sutcliffe coefficient for period of calibration and both variants of models (TI for temperature index method, EN for energy balance) are:

Catchment	NS - TI	NS- EN
Cerna Nisa	0.63	0.61
Cerna Desna	0,63	0,67
Kamenice	0,70	0,71

Mean values of Nash-Sutcliffe coefficient for period of validation are:

Catchment	NS - TI	NS- EN
Cerna Nisa	0.47	0.49
Cerna Desna	0,70	0,76
Kamenice	0,69	0,68

The average values of Nash-Sutcliffe coefficient, produced by the version with energy balance method are slightly better, but there is no statistical evidence, that the mean values of Nash-Sutcliffe coefficient significantly differ (on the level of α = 0.05).

5 CONCLUSIONS

The first results indicate, that there is possibility of use the simplified energy balance method for runoff prediction without loss of accuracy. It is necessary to make more tests, especially for the periods of snowmelt and to test the simulation of snow water equivalent, in places, where are these datasets available. Advantage of the energy balance method is the elimination of calibration parameters, which are usually needed for temperature-index methods.

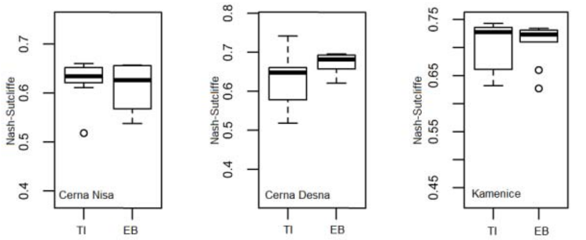

Figure 3. Distribution of Nash-Sutcliffe coefficient values during period of calibration.

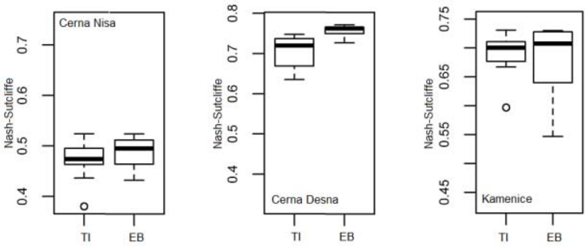

Figure 4. Distribution of Nash-Sutcliffe coefficient values during period of validation.

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