APPLICATION OF MODEL METQ FOR THE RIVER BASINS UNDER DIFFERENT NATURAL CONDITIONS IN LATVIA

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Abstract

In this paper, results acquired by the new version of the model METQ for seven different pilot river basins in Latvia – the Iecava, the Malta, the Pērse, the Vienziemīte, the Malmuta, the Vircava and the Imula are presented. These pilot river basins are characterised by one or two predominant natural condition such as hilly agricultural lands, agricultural lowlands, sandy lowlands, forested areas, swamps or lakes. Similarly to previous versions of the model METQ, the METQ2007BDOPT is applied for the simulation of the daily runoff for rivers with different catchment areas. The calibration of the model was done for the various periods of river runoff observation records from 1956 to 2006. Sufficient or even good coincidence between the observed and simulated daily discharges was obtained. The efficiency criterion R^2 varies between 0.60 and 0.78, but the correlation coefficient r - between 0.82 and 0.88.

Keywords: simulation of daily runoff, conceptual model, river basin

INTRODUCTION

The river basins of Latvia are characterized by different natural conditions – uneven relief, humid climate and geological development. These natural conditions are important aspects in hydrological regime of rivers. However, not always all parameters of hydrological regime or river basins have been observed. One of the explanations is that hydrological monitoring is rather expensive and there have been financial problems during the last fifteen years in Latvia. One possible method is the use of conceptual rainfall-runoff models which are widely used tools in hydrology (Seibert, 1999; Uhlenbrook et al., 1999; Beven, 2001; Zīverts and Apsīte, 2001; Jayawardena, 2006).

The extension of runoff series in time and space, i.e., regionalisation of conceptual rainfall-runoff models, is rather straightforward. During the past decades this approach has been tested by several scientists with varying success (Braun and Renner, 1992; Seibert, 1999; Merz and Blöschl, 2004; Parajka et. al., 2005; Götzinger and Bárdossy, 2007). Kite and Kouwe (1992) have concluded that there is risk for bias in the model calibration. This risk is obvious for manual calibration, because the modeller may search the optimal parameters influenced by what he expects. Using automatic calibration procedures different parameter sets may be found dependent on, for instance, start values of the parameter search.

The aim of this study is to calibrate the conceptual model METQ2007BDOPT for the small rivers basins under different natural conditions, and to find relationships between parameter values and physiographic basin characteristic.

MATERIAL AND METHODS

The latest version METQ2007BDOPT and its application

In Latvia, during the last twenty years, several versions of mathematical models of hydrological processes have been developed – METUL (Krams and Ziverts, 1993), METQ96 (Ziverts and Jauja, 1996), METQ98 (Ziverts and Jauja, 1999). The METQ is a conceptual rainfall-runoff model of catchment hydrology, originally developed for Latvian catchments. In this study, the latest version METQ2007BDOPT is applied for the simulation of the daily runoff. The model parameters are basically the same as in the METQ98 (Ziverts and Jauja, 1999). The METQ2007BDOPT has one additional Beta parameter, providing twenty three parameters in total (Table 1). However, most of the parameters could be estimated by manually or semi-automatically calibration technique. Snow accumulation and melting characterises the following parameters: T_1 –daily mean temperature ^{0}C, at which starts snow accumulation; T_2 – daily mean temperature at which starts snow melting; CMELT is degree – day ratio and characterise intensity of snow melting; AMELT – conversation factor which increase degree-day ratio on the daily potential isolation of each particular day; KS – evaporation coefficient from snow; WHC and CFR characterise the snow accumulation and melting processes. The water balance from root zone characterise: WMAX – threshold value of water storage in root zone (mm); KU and KL – coefficients characterise the intensity of evaporation from the root zone; RCHR, RCHRZ, RCHR2, RCHR2Z and ROBK – characterise the infiltration capacity of soil. The water balance of groundwater storage and runoff characterise following parameters: ALFA – fillabale porosity of the aquifer; ZCAP – height of capillary rise (cm); DZ –depth of upper level drain from; A2 and Beta characterize daily subsurface runoff Q_2 of upper level „drain"; PZ characterises the depth of the lower level "drain"; A3 – the daily runoff Q_3 of the lower level "drain"; DPERC is intensity of the deep percolation to the aquifers, mm/day. Most of the parameters are physically based and usually in the METQ model the rest of parameters could be estimated by the calibration. The METQ2007BDOPT has semi automatic calibration performance for the following parameters – A2, DZ, A3, PZ, CMELT, AMELT, DPERC, Beta, RCHR, RCHR2, RCHRZ, and RCHRZ2.

Also in the METQ2007BDOPT model, to consider the runoff heterogeneity in runoff processes, the studied river basin were divided into hydrological response units (HRU). The HRUs characterized by a relative homogeneity with the respect to the most important parameters, which include slope, vegetation and soil characteristics. Everyone studied pilot river basins were divided into six 6 HRUs: agricultural lowlands, hilly agricultural lands, forests, swamps, sandy lowlands and lakes. However, in this study seven pilot river basins by one or two predominant HRUs or natural conditions were chosen. The River Pērse basin was characterised with hilly agricultural lands and forests; the Brook Vienziemīte basin – hilly agricultural lands; the River Imula basin – agricultural hilly and lowlands; the River Vircava basin – agricultural lowlands; the River Iecava (upper reaches) basin – sandy lowlands; the River Malmuta basin – bog areas and the River Malta basin – lakes.

The water balance and runoff of each HRU has been simulated in three storages (Ziverts and Jauja, 1999): snow, soil moisture and groundwater. The total runoff from each HRU consists of three runoff components: Q_1 – surface runoff, Q_2 – subsurface runoff (runoff from the groundwater upper zone) and Q_3 – base flow (runoff from the groundwater lower zone).

Input data for the model are daily meteorological data. In present study, observation data of twelve meteorological and seven gauge stations were applied for the calibration performance (Figure 1). The calibration of the model was done for the various periods of river runoff observation records from 1956 to 2006. To do the analyses of the results of model calibration, a statistical criterion R^2 (Nash and Sutclife, 1970), a correlation coefficient *r* and average values were used.

Study sites

In this study the chosen seven river basins are located in different places of Latvia and belonged to the three largest river basins – the Daugava, the Lielupe and the Venta. To according Pastor's (1987) regionalization of Latvian small rivers, the River Pērse basin belongs to the rivers' region of the Vidzeme Highland. Total drainage basin is 329 km^2, but upstream hydrological station Ūsiņi – 249 km^2. The average amount of precipitation is 800 mm per year. The area of River Iecava drainage basin upstream hydrological station is 519 km^2, and it makes 1166 km^2 in total. The average amount of precipitation ranges from 650 to 750 mm per year. The River Iecava belongs to hilly the Upmale Plain and the Taurkalnes Plain. The Brook Vienziemīte basin area is 5.92 km^2 and it belongs to the rivers' of Vidzeme Upland. The River Vircava basin belongs to the rivers' of the Zemgale Lowland and there average amount of precipitation is 599 mm per year. The total area of the River Vircava basin is 423 km^2. The River Imula basin belongs to the Austrumkursas Upland and total basin area is 263 km^2. The average amount of precipitation varies from 650 to 700 mm per year.

Comparing with other river basins, the River Vienziemīte basin receives the highest amount of precipitation, because it's located in the Vidzemes Upland. This basin characterizes also by high percentage of hilly agricultural land - 46 % cover of total basin. The most forested areas are in the Pērse River basin. Regardless of the Malta and the Malmuta river basins location in the same hydrological region, they are still different in predominant HRU. The River Malta is substantially affected by the lakes (about 35%), while the River Malmuta basin - by bogs' area (about 40%). The River Iecava basin is quite different from other river basins in terms of geomorphologic conditions. There are sandy lowlands dominating upstream of the River Iecava basin, as well as forests. The River Vircava basin is characterized by agricultural lowlands which occupies 56 % of the total drainage basin. However, the River Imula basin characterises by agricultural hilly lands (62 %).

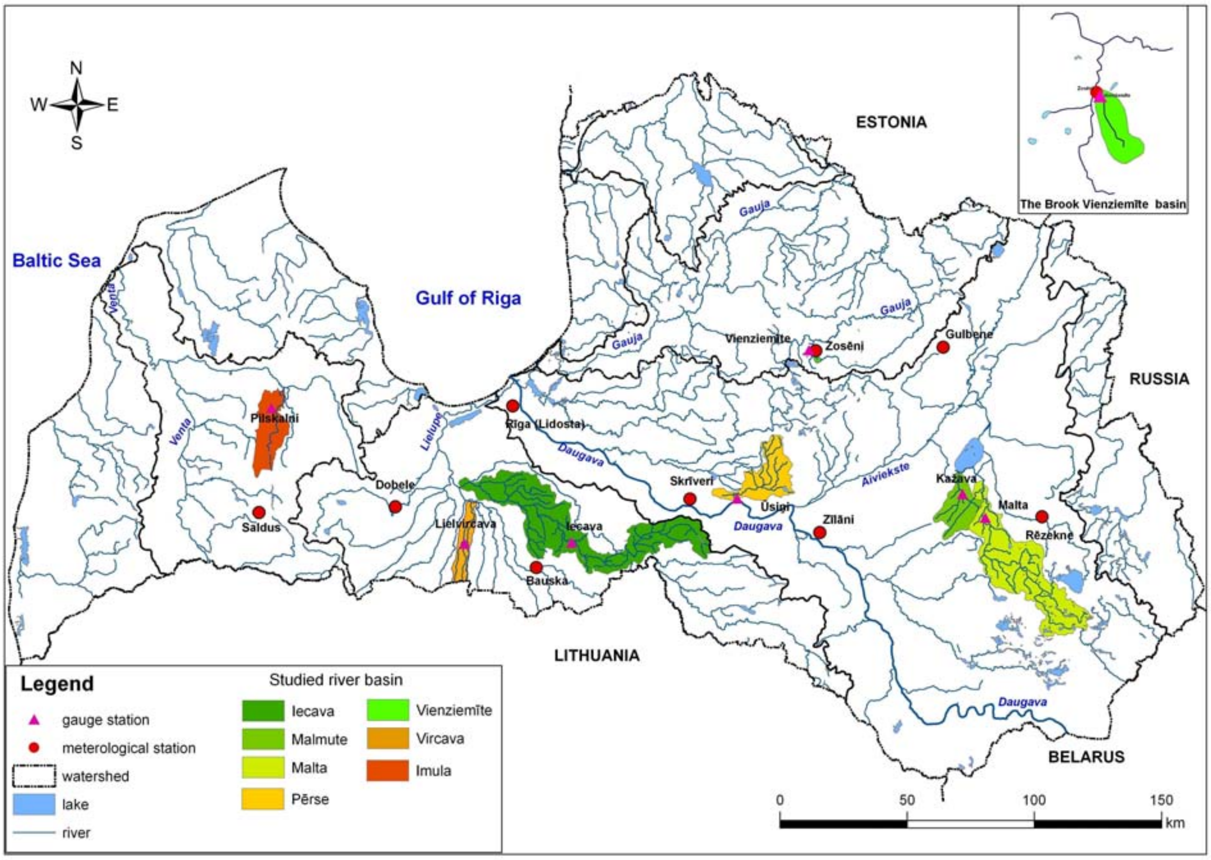

Figure 1 The locations of gauge and meteorological stations and the study areas

RESULTS AND DISCUSSIONS

The conceptual rainfall-runoff model METQ2007BDOPT were calibrated to the seven pilot river basins for the various periods of river runoff observation records from 1956 to 2006. We have obtained sufficient or even good coincidences between the observed and simulated daily discharges (Fig. 2-4). The model calibrations results are following: correlation coefficient r is 0.88 and statistical criterion R^2 – 0.78 for the River Malta at Viļāni (1976 – 1995); r – 0.87 and R^2 – 0.77 for the Brook Vienziemīte at Vienziemīte (1956 – 2002); r – 0.85 and R^2 – 0.72 for the River Pērse at Ūsiņi (1956 – 2006); r – 0.82 and R^2 – 0.66 for River Iecava at Dupši (1956 – 1995); r – 0.63 and R^2 – 0.80 for the River Vircava at Lielvircava (1983 – 2006); r – 0.78 and R^2 – 0.60 for the River Malmuta at Kažava (1980 – 2006); and last one r – 0.77 and R^2 – 0.66 for the River Imula at Pilskalni (1956 – 1995). We can conclude that the best coincidence between simulated and observed daily discharge was found for the River Malta but the weaker – for the River Malmuta at Kažava.

The main source of difference between the simulated and observed runoff values is the quality of precipitation input data and the location of the available meteorological stations to characterize the spatial and temporal distribution of precipitation in the drainage basins. As mentioned before, the best coincidence was identified for the River Malta basin and it is due to precipitation observations in the river basin. There is a meteorological station at Viļāni and its data could be used for the model calibration.

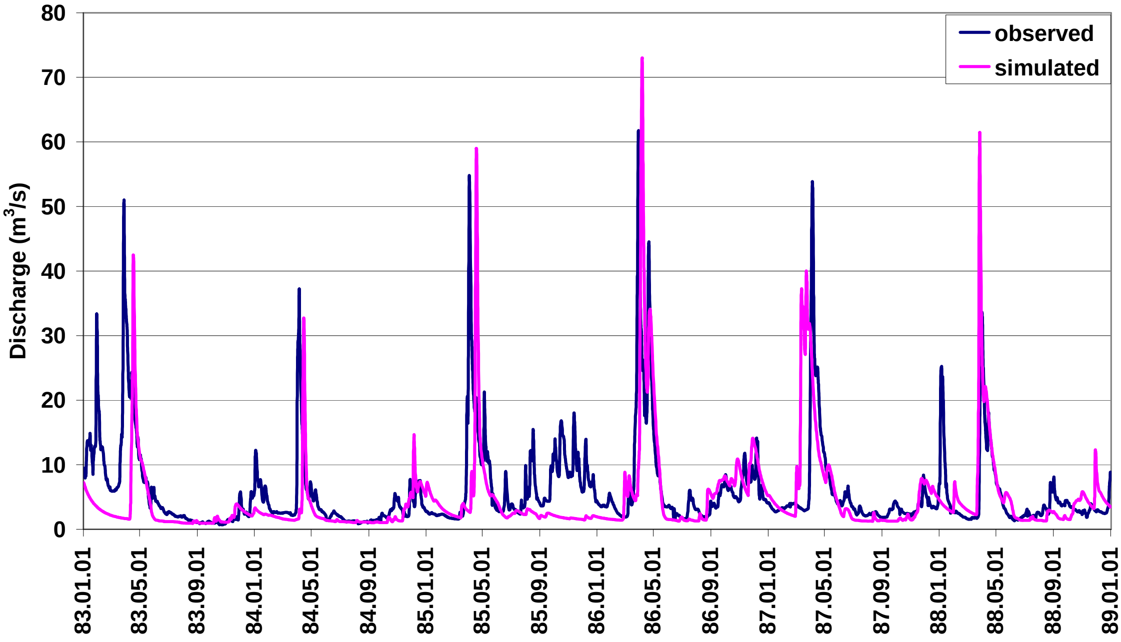

Figure 2 Observed and simulated daily discharge at runoff gauge station Malta – Viļāni

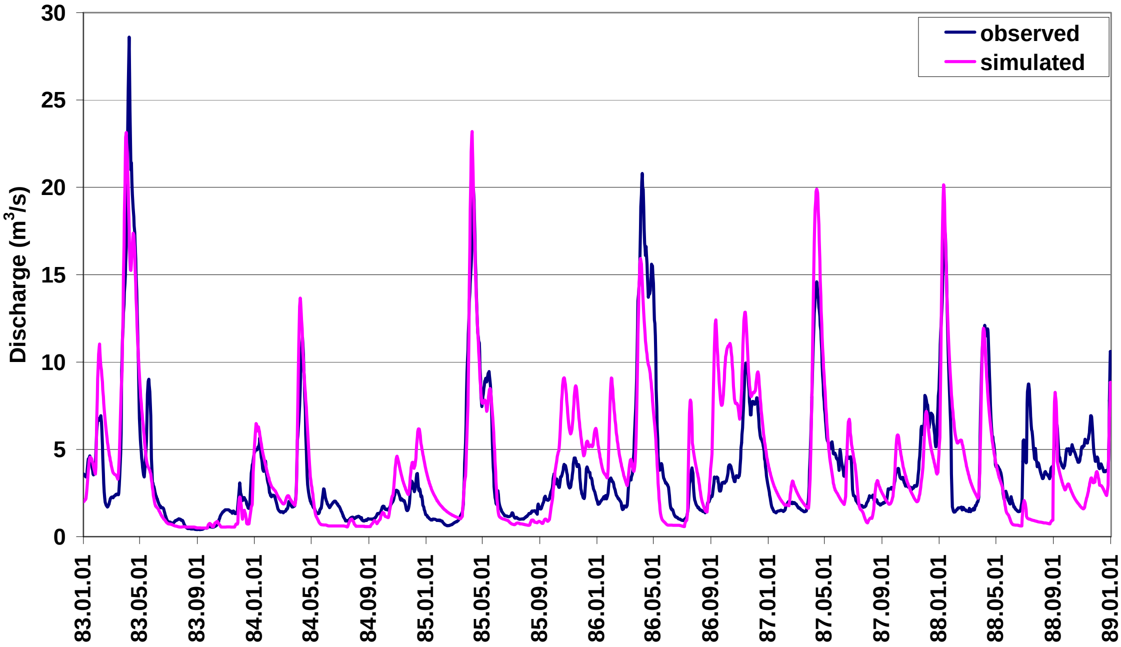

Figure 3 Observed and simulated daily discharge at runoff gauge station Iecava – Dupši

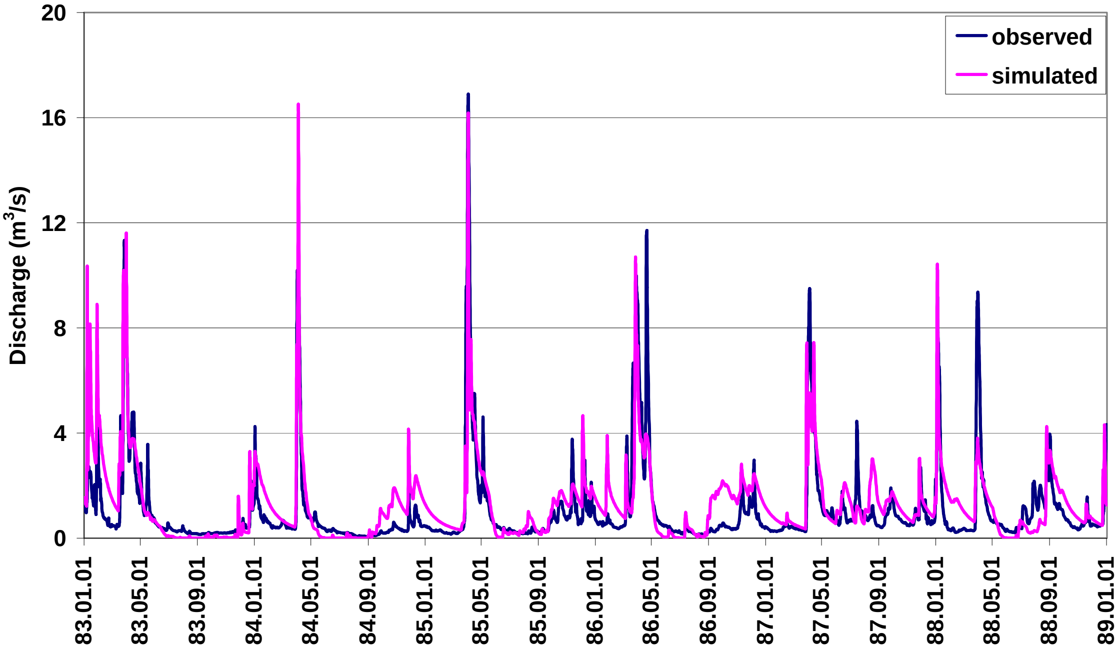

Figure 4 Observed and simulated daily discharge at runoff gauge station Malmuta – Kažava

For instance, there are no meteorological stations in the River Iecava basin. Therefore meteorological stations at Bauska, Skrīveri and Rīga (Riga airport) have been used. The weaker coincidence was identified for the River Malmuta basin and one of the reasons could be insufficient meteorological observations to do better model calibration. Since large areas of bogs in river basin play an important role in the generation of the river runoff, meteorological observations of evaporation from bogs are important for such basins. Another explanation is connected with not well marked riverbed.

Optimized parameters of the model METQ2007BDOPT for the seven studied small river catchments with gauge stations (as results of calibration) are shown in the Table 1. The numerical values of model parameters for each river basin reflect the physiogeographical conditions, including geomorphological, land use, soil etc., of the studied drainage areas.

Estimation of threshold value of water storage in the root zone is based on the previous studies of irrigation regime in Latvia (Ziverts and Jauja, 1999). In the river basins rich in bogs, i.e. the River Malmuta basin, value of WMAX is 20 mm. Soil conditions play an important role in the runoff generation. According to the results, fillabale porosity (ALFA) is one of the main parameters which could reflect the geomorphologic conditions of rivers basin. The highest parameter value of ALFA was defined for the River Iecava basin. It may be explained by dominating sandy lowlands. In accordance with the hydrophysical properties of the soil structure, the highest value of fillabale porosity is for sands. Height of capillary rise (ZCAP) depends on the soil grading composition. The highest value of ZCAP was identified for the heavy soils, i.e. the River Pērse basin, while these values are lower for light soils like sandy ones. Value of coefficient of snow melting (CMELT) in the river basin is higher in more open, not forested areas such as the River Vircava basin. The results obtained from the model calibration show that the model METQ2007BDOPT is widely applicable for this kind of pilot basins.

Table 1. Optimized parameters of the model METQ2007BDOPT for the studied river basins (decoding of the model parameters see in chapter Materials and methods)

Parameters	The name of studied river basin						
	Pērse	Malta	Imula	Vircava	Iecava	Vienziemīte	Malmuta
WMAX, mm	35	30	30	70	34	35	20
ALFA	0.074	0.124	0.08	0.05	0.18	0.135	0.15
ZCAP, cm	140	130	140	150	125	110	60
A2	0.0006	0.0006	0.0007	0.001	0.0009	0.00076	0.0004
A3	0.00073	0.00079	0.0006	0.00088	0.0008	0.00056	0.0006
KU	0.56	0.61	0.61	0.57	0.57	0.62	0.58
KL	0.26	0.26	0.26	0.25	0.23	0.32	0.25
CMELT	2.5	3	2.9	3.5	2.5	3.4	2.5
T1, ^{0}C	0.5	0.5	0.5	0.5	0.4	0.5	0.5
T2, ^{0}C	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
KS	0.05	0.05	0.05	0.05	0.05	0.05	0.05
DZ, cm	70	100	100	40	75	65	40
PZ, cm	210	305	235	210	216	270	60
RCHR, mm/d	4	48	23	3	23	3	25
RCHRZ, mm/d	5	5	10	6	10	7	6
RCKR2, mm/d	21	14	20	45	67	70	25
RCHR2Z,mm/d	12	12	18	25	25	8	4
ROBK	1.5	1.5	1.5	1.5	1.4	1.5	1.5
WHC	0.1	0.1	0.1	0.1	0.1	0.1	0.1
CFR	1.2	1.2	1.2	1.2	1.2	1.2	1.2
DPERC,mm/d	0	0	0	0	0	0.04	0
AMELTK	0.08	0.05	0.05	0.09	0.08	0.08	0.07
BETA	2.1	2	2	2	2.1	2.2	2

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