1. HBV

The HBV (Bergström, 1992) is a well known conceptual rainfall-runoff model. Based on its history e.g. (Das, Bárdossy, Zehe, and He, 2008; Götzinger and Bárdossy, 2007; Hundecha and Bárdossy, 2004) in this study area and simplicity, the authors have chosen to use a slightly modified version that conserves mass. To start with, it needs a precipitation, a temperature, and a potential evapotranspiration (PET) time series. It can be run in a spatially lumped or a distributed configuration. A schematic diagram and the equations of a lumped configuration are given here. In order to obtain sets of equally good model parameters, the Robust Paramter Estimation (ROPE) procedure Bárdossy and Singh (2008) was used.

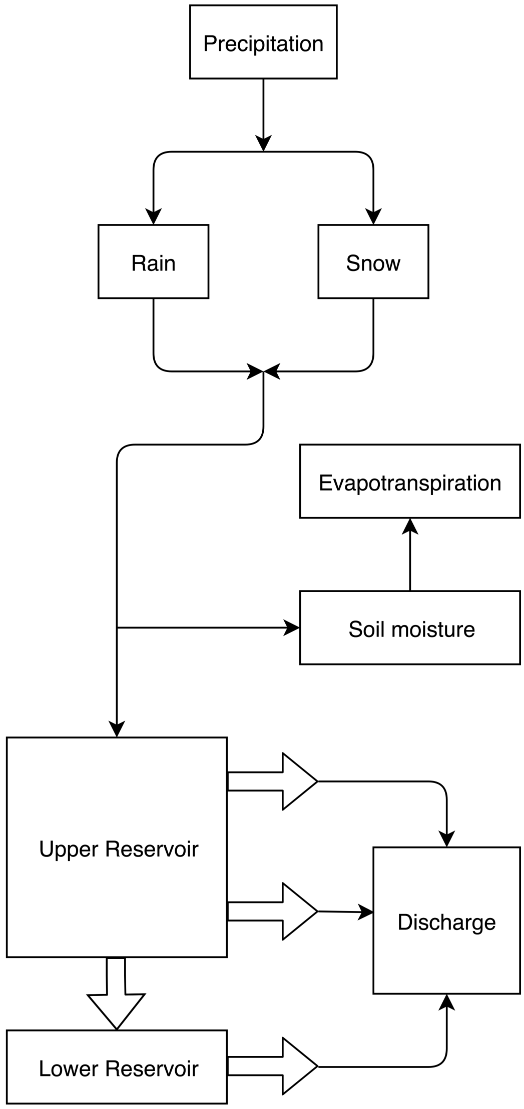

Figure 1. The HBV model

Snow melt and accumulation

$$ME_i = max(0.0, (CM_{TE} + (CM_{PR} \cdot PR_i)) \cdot (TE_i - TT)) \tag{1}$$

$$SN_i = \begin{cases} SN_{i-1} + PR_i & \text{if } TE_i <= TT, \\ SN_{i-1} - ME_i & \text{else.} \end{cases} \tag{2}$$

$$LP_i = \begin{cases} 0.0 & \text{if } TE_i <= TT, \\ PR_i + min(SN_{i-1}, ME_i) & \text{else.} \end{cases} \tag{3}$$

where the subscript i is the index of a given day, CM_{TE} is the snow melt due to increase in temperature in $mm/°C \cdot day$, PR_i is the precipitation in mm/day, CM_{PR} is the snow melt due to falling liquid precipitation in $mm/°C \cdot day \cdot mm\ of\ PR_i$, TE_i is the temperature in $°C$, TT is the threshold temperature below which the precipitation falls as snow, ME_i is the possible snow melt in mm, SN_i is the total accumulated snow in mm, LP_i is the liquid precipitation in mm that might come from snow melt or precipitation or both.

Evapotranspiration and soil moisture

$$AM_i = SM_{i-1} + (LP_i \cdot (1 - (SM_{i-1}/FC)^{\beta})) \tag{4}$$

$$ET_i = \begin{cases} min(AM_i, PE_i) & \text{if } SM_{i-1} > PWP, \\ min(AM_i, (SM_{i-1}/FC) \cdot PE_i) & \text{else.} \end{cases} \tag{5}$$

$$SM_i = max(0.0, AM_i - ET_i) \tag{6}$$

where SM_i is the soil moisture in mm, FC is the field capacity in mm, PWP is the permanent wilting point in mm, β is a unitless constant related to the soil's ability to retain moisture, AM_i is the available soil moisture in mm, PE_i is the potential evapotranspiration in mm/day, ET_i is the actual evapotranspiration in mm/day.

Upper reservoir runoff routing

$$RN_i = LP_i \cdot (SM_{i-1}/FC)^{\beta} \tag{7}$$

$$UR\_UO_i = max(0.0, (UR\_ST_{i-1} - UT) \cdot K_{uu}) \tag{8}$$

$$UR\_LO_i = max(0.0, (UR\_ST_{i-1} - UR\_UO_i) \cdot K_{ul}) \tag{9}$$

$$UR\_LR_i = max(0.0, (UR\_ST_{i-1} - UR\_UO_i - UR\_LO_i) \cdot K_d) \tag{10}$$

$$UR\_ST_i = max(0.0, (UR\_ST_{i-1} - UR\_UO_i - UR\_LO_i - UR\_LR_i + RN_i)) \tag{11}$$

where RN_i is the runoff in mm/day i.e. the amount of water that is not retained by the soil and is available for routing through the model's reservoirs, UR_ST_i is the upper reservoir storage in mm, UT is the storage threshold in mm above which quick runoff from the upper outlet of the reservoir should take place. K_{uu} is the upper reservoir upper outlet's runoff coefficient in day^{-1}, UR_UO_i is the runoff in mm/day from the upper reservoir upper outlet, K_{ul} is the upper reservoir lower outlet's runoff coefficient in day^{-1}, K_d is the coefficient of runoff transfer from the upper to lower reservoirs in day^{-1}, UR_LO_i is the runoff from the upper reservoir's lower outlet in mm/day.

Lower reservoir runoff routing

$$LR\_O_i = LR\_ST_{i-1} \cdot K_{ll} \tag{12}$$

$$LR\_ST_i = LR\_ST_{i-1} + UR\_LR_i - LR\_O_i \tag{13}$$

where LR_ST_i is the lower reservoir storage in mm, K_{ll} is the lower reservoir runoff coefficient in day^{-1}, LR_O_i is the runoff from the lower reservoir in mm/day.

Simulated discharge

$$QS_i = (UR\_UO_i + UR\_LO_i + LR\_O_i) \cdot CC \tag{14}$$

where CC is a conversion constant that converts mm/day to m^3/sec in our case, QS_i is the simulated discharge in m^3/sec.

References

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