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Uncertainty analysis of a three-parameter Budyko-type equation at annual and monthly time scales

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The Budyko curves can estimate mean annual evaporation in catchment scale as a function of precipitation and potential evaporation. They are used for the steady-state catchments with the negligible water storage change. In the non-steady-state catchments, especially the irrigated ones, and in the small spatial and temporal scales, the water storage change is not negligible and, therefore, the Budyko curves are limited. In these cases, in addition to precipitation, another water resources are available for evaporation including groundwater depletion and initial soil moisture. Therefore, evaporation exceeds precipitation and the data does not follow the original Budyko framework. In this study, the two-parameter Budyko equation of Greve et al. (2016) was considered. They proposed a Budyko-type equation in which they changed the boundary condition of water-limited line and added a new parameter to the Fu equation. Based on Chen et al. (2013)'s suggestion, in arid regions where aridity index is more than one, the Budyko curve can be shifted to the right direction of aridity index axis. Therefore, in this study, we combined Greve et al. (2016)'s equation and Chen et al. (2013)'s equation and proposed a new equation with three parameters (y_0, k, c) to estimate the monthly and annual evaporation of five semi-arid watersheds in Kavir-e-Markazi basin.

$$\frac{E}{P} = F(\phi, y_0, k, c) = 1 + (\phi - c) - (1 + (1 - y_0)^{k-1}(\phi - c)^k)^{\frac{1}{k}}$$

In this equation E, P and Φ are evaporation, precipitation and aridity index, respectively. To calibrate the new Budyko curve, we used the evaporation estimated by water balance equation for 11 water years (2002-2012). Due to the variability of watersheds characteristics and climate conditions, we used the GLUE (Generalized Likelihood Uncertainty Estimation) to calibrate the proposed equation to increase the reliability of the model. Based on the GLUE, the parameter sets with the highest value of likelihood were estimated as y_0=0.02, k=3.70 and c=3.61 at annual scale and y_0=0.07, k=2.50 and c=0.97 at monthly scale. The results showed that the proposed equation can estimate the annual evaporation reasonably with R^2=0.93 and RMSE=18.5 mm year^{-1}. Also it can estimate evaporation at monthly scale with R^2=0.88 and RMSE=7.9 mm month^{-1}. The posterior distribution function of the parameters showed that parameters uncertainty would decrease by GLUE method, this uncertainty reduction (and therefore the sensitivity of the equation to the parameters) is different for each parameter.

Chen, X., Alimohammadi, N., Wang, D. 2013. Modeling interannual variability of seasonal evaporation and storage change based on the extended Budyko framework. Water Resources Research, 49(9):6067–6078.

Greve, P., Gudmundsson, L., Orlowsky, B., Seneviratne, S.I. 2016. A two-parameter Budyko function to represent conditions under which evapotranspiration exceeds precipitation. Hydrology and Earth System Sciences, 20(6): 2195-2205. DOI:10.5194/hess-20-2195-2016.