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Modeling karst spring discharge in relation to standardized precipitation indices: a new method for forecasting water scarcity conditions

E. Romano, A. Del Bon, A.B. Petrangeli, and E. Preziosi
National Research Council, Water Research Institute, Roma, Italy (romano@irsa.cnr.it)

In Umbria Region (Central Italy) approximately the 35% of water for human use comes from 30 karst springs different in discharge, recharge time and storage capacity. Only 16 of these springs are currently monitored by the Regional Environmental Protection Agency and only five out of these 16 are monitored since 1998. For the remaining 14 springs only very few information is usually available: the long term average annual outflow and the long term average minimum outflow. In this context it is fundamental for management purposes to study the relations between the evolution of the rainfall input overall the basin and the distribution in time and space of the stored resources, in relation to the present or future basin climatic conditions. The main objective of this study is to develop a method to generate long term hydrographs for the springs of which only a very few information is available (i.e. an estimate of the average discharge and of the average minimum annual discharge), consistent with the precipitation regimen. To this goal, a new method has been proposed, grounded on three main points: a. capture from the available precipitation and discharge data the main statistics describing the relations between rainfall regimen and outflow for karst springs in the study area; b. verify how far these relations can be generalized to similar springs in the region; c. use them for generating synthetic outflow time series coherent with the precipitation time evolution at basin scale. The method can be summarized in seven steps: 1. Validation of the outflow model, based on the assumption that the yearly spring hydrograph is divided in one linear continuous recharge phase, starting at the end of the previous recession phase, and one exponential continuous discharge phase starting at the end of the recharge; thus for each hydrologic year the hydrograph is completely described by the maximum and minimum outflow and the duration of the recharge and discharge phases (called "outflow parameters"). 2. Computation of the linear correlation coefficients between the observed long term average outflow parameters. 3. Computation of the Standardized Precipitation Index (SPI) at local and basin scale for the period 1952-2010. 4. Correlations SPI – outflow parameters. For each spring, the correlation coefficient between each outflow parameter and the basin standardized precipitation indices at different aggregation time have been computed, to assess which aggregation time step n of the SPI best correlates with each outflow parameter. 5. Assessment of the variability in time of the spring parameters, assigned assuming that the standard deviation of each generic parameter is proportional to the standard deviation of the SPI. 6. Validation of the generation method. Synthetic hydrographs for the monitored springs have been generated, to be compared to the observed . 7. Generation of synthetic time series. Using the information from steps 1-6, an estimate of the average discharge and of the average minimum annual discharge, synthetic hydrographs related to the observed precipitation regimen have been generated for a generic unknown spring. This method doesn't expect to fully replace monitoring activities; however it could be used to generate a reasonable estimate of single spring hydrographs, when a large number of similar spring exist in the same region, having only detailed information on the main ones.