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Artificial neural network modeling of fragmented rainfall-runoff processes in various climates

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The natural climatic variability in floods, droughts, low and medium magnitude river flows, is of particular interest and importance in operational hydrology where crucial decisions need to be taken, such as issuing warnings during floods and droughts, or routine operation and management of water supply systems. Variations in such events have been linked to large-scale atmospheric circulation in the form of both the North Atlantic Oscillation (NAO) and weather types. The Mesochora river catchment, which has been selected for the study, lies in the northwestern part of Greece in a fairly mountainous area influenced to a large extent by NAO behavior. The plot of the long-term annual catchment pseudo-precipitation (rain plus snowmelt) simulated by the snow accumulation and ablation model (SAA) of the US National Weather Service (US NWS) showed trends of three climatically distinct periods, characterised by clearly descending, rising and moderately descending segments in pseudo-precipitation. The employed snowmelt model is a deterministic, continuous conceptual model, consisting of a set of mathematical formulations, which explicitly describes the change in storage of water and heat in the snowpack, based on precipitation and temperature at 6-hourly intervals. An algorithm coupling linear least squares and simplex optimization (LLSSIM) is used to examine the ability of a three- layer feedforward artificial neural network (ANN) to simulate the rainfall-runoff relationship partitioned in high (x$>\mu$+2σ), medium ($\mu \leq$ x $\leq \mu$+2σ) and low (x $< \mu$) flows during the various climates as revealed by the pseudo-precipitation. The ANN model was calibrated for each of the three climate types and each was validated against the others. A variety of statistical performance parameters and graphs showed the effectiveness and efficiency of the ANN model in capturing the continuous and fragmented rainfall-runoff relation-

ship under various climates and transient conditions. The statistical evaluation criteria used, were the threshold statistics (TS) for absolute relative error (ARE) levels of 1-, 5-, 25-, 50-, and 100-percent, the average absolute relative error (AARE), the coefficient of correlation (R), the normalized mean bias error (NMBE) and the normalized root mean square error (NRMSE). The TS and AARE statistics (in terms of predicting flows and distribution of errors) measure the effectiveness of the model regarding its ability to accurately predict data from a calibrated model, which, in this case are high, medium and low magnitude flows. The other statistics, R, NMBE, and NRMSE quantify the efficiency of a model in capturing the complex, dynamic and nonlinear rainfall-runoff process. The majority of data points are in low magnitude flow category both during calibration and validation sub-periods of pseudo-precipitation. The ANN model proved capable to simulate well the daily high, medium and low magnitude flows when calibrated for increasing pseudo-precipitation and validated for moderately decreasing pseudo-precipitation. For the same catchment and time period, similar findings have been revealed by considering the above and below the mean daily flows, as high and low flows respectively and by using different statistical evaluation measures (e.g. RMSE, %VE, %MF). For the entire period, the ANN model provided a better representation of partitioned rainfall-runoff process (into high, medium and low magnitude flows) than the deterministic conceptual soil moisture accounting (SMA) model of the US NWS, which was employed in this study. Recent research suggests that the inclusion of selected deterministic components of a conceptual rainfall-runoff model in the input vector of the ANN model (here, rain plus snowmelt), or the disintegration of hidden neurons in the ANN rainfall-runoff model in order to approximate various components of the hydrological system (e.g. infiltration, surface flow, etc), can assist in incorporating more physical reality in the system's theoretical model and can result in minimising errors. Even so, these improved ANNs are truly representing the physical components of the whole system and are thus by no means substitutes for the physically based models, such as the SMA model employed here. However, it is suggested that the ANN approach provides a viable and effective alternative for simulating fragmented rainfall-runoff timeseries and forecasting daily high, medium and low flows in climatically varied conditions, particularly in cases where the internal dynamics of the catchment do not require an explicit representation.