Geophysical Research Abstracts,
Vol. 10, EGU2008-A-03801, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-03801
EGU General Assembly 2008

Streamflow prediction in ungauged catchments using a copula-based similarity measure

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In this paper we propose a method to estimate daily streamflow time series in an ungauged basin using a process-based distributed hydrologic model (HBV-UFZ) and sets of model parameters obtained from donor basins. Suitable donor basins are those whose distance to the ungauged catchment in a m-dimension embedding space is the least. The embedding space is found as a linear or nonlinear transformation of the n-dimension space ($n > m$) of the catchment descriptors.

The main condition for the embedding space is that a small distance between a given pair of basins implies a similar hydrological response. To guarantee that this condition is always true, the parameters required to define this embedding space are obtained with a local variance minimisation technique using a similarity measure derived from runoff copulas of all pairs of donor basins. The copula-based similarity measure is estimated based on the upper- and lower-tail moments of a runoff copula which denote mainly the climatic and morphologic similarities respectively. It should be emphasised that the scale invariance property of a copula is quite advantageous for defining a similarity measure. The streamflow prediction for an ungauged basin is the ensemble mean of the streamflows generated by the hydrological model using parameters obtained from its k-nearest neighbouring donor basins. Such features constitute the main differences of this technique with respect to other standard procedures reported in the literature in which the similarity measure and the distance is always determined in the original space of the predictors, which not necessarily fulfill the condition mentioned above.

To illustrate the application of this technique, 34 southern German basins ranging

from 70 to 4200 km^2 were selected. For each basin a number of catchment descriptors were quantified, e.g. mean slope, aspect, shape factor, mean elevation, and several climatic indices such as the antecedent precipitation index and mean monthly temperature. Daily streamflow time series correspond to the period from 1961 to 2000. The hydrologic model used regionalized parameters whose nonlinear transfer function parameters were calibrated with adaptive simulated annealing.

The results were validated with Jackknife crossvalidation against daily discharge observations. Nash-Sutcliffe efficiencies in the calibration and validation phases ranged between 0.70 to 0.85 and between 0.55 to 0.75 respectively. Uncertainty and crossvalidation analyses showed that the proposed technique produced reasonable results for ungauged basins.