Geophysical Research Abstracts, Vol. 7, 09343, 2005
SRef-ID: 1607-7962/gra/EGU05-A-09343

Consensus modelling of environmental flows

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The estimation of environmental flows generally requires long stream flow records that represent natural flow regimes. In a practical context, for instance when specifying minimum flows for hydropower operation or other water uses, estimates are usually required for sites where the natural river flow regime has been altered in recent years and/or no stream flow records are available. Regionalisation techniques can be used to infer environmental flows from neighbouring, undisturbed catchments where stream flow data have been collected. For hydrologically complex regions the spatial transposition may involve considerable errors. Often, various models are justifiable which yield different estimates. In this paper an approach is proposed that combine information from different sources (model estimates, local data, internal information from hydropower operators) in a consistent way. This combination is termed a consensus modelling approach here and is illustrated by estimating annual and seasonal low flow pattern for 270 hydropower sites in Austria.

The estimation of annual low flows is based on several models: (1) a regional regression model based on a grouping of catchments according to low flow seasonality; (2) the same regional regression model, locally calibrated to satisfy sub-catchment water balance (long-term records and short-term records adjusted for climate variability); (3) the same regression model, but large catchments (area > 50 km^2) smoothed by local (r = 20 km) altitude regression; (4) local estimates, i.e. inference of specific low flow from similar and nearby catchment (gauged and predicted catchments); (5) information (measurements and estimates) from the hydropower operators, associated with varying accuracy. The regional regression model was developed in an earlier study. The plausibility of the estimates was examined by inspecting their regional pattern in a GIS and expert judgement. Whenever the default model estimate appeared not to be

consistent with hydrological reasoning, the use of alternative estimates was considered. In this case, the alternative estimate was weighted according to their perceived reliability relative to the default estimate (0%, 50%, 100%) and combined with the default estimate by a weighted average. The regional comparison of estimates from different models was used to formulate general application rules of the concurrent models as an iterative process.

The estimation of the seasonal (monthly) low flow pattern, again, combines various models. The models for the annual low flows are combined with information from a gridded (soil moisture accounting) catchment model. For catchments which exhibit altered low flow regimes due to storage or abstractions, model parameters have been inferred from similar natural catchments. Since large parts of the study area exhibit altered low flow regimes, the model is locally not very well calibrated in some catchments and exhibits biases. Monthly low flows have therefore been adjusted to the annual low flows or, alternatively, by regional regressions against catchment altitude.

For both parts of the study, results indicate that consensus modelling is a viable method in practical applications of regionalisation models. The combination of different sources of information is attractive in the presence of uncertainty in the input data and models.