CERIS Civil Engineering Research and Innovation for Sustainability

On flow duration curve modelling in Alpine catchments

Summary

Mountain regions are considered to be the natural "water towers" of the world due to their importance as sources of many rivers. Reliable tools to estimate the availability and variability of streamflows in such regions are still rare. In this context, the present Thesis proposes to extend an existing Flow Duration Curve (FDC) modelling framework to Alpine environment. Such curves show the percentage of time a streamflow value is equaled or exceeded during a reference period and thereby give a representation of the probabilistic distribution of daily streamflows.

FDCs can be obtained empirically or based on models. Process-based FDC models have the advantage of incorporating hydrological process knowledge and thereby allowing the prediction of FDCs under changing conditions. This Thesis studies a simple process-based model that describes daily streamflow distributions as the result of subsurface flow pulses triggered by stochastic rainfall and censored by the soil moisture dynamics. The resulting streamflow distribution is characterized by only a few parameters: the mean rainfall depth and the frequency of rainfall events that produce streamflow and recession parameters.

The objective of this Thesis is the extension of the existing framework, originally developed by Botter *et al.* (2007c) for pluvial streamflow regimes to Alpine environments where the accumulation of water in the form of snow and ice influences the streamflow regime. The selected study region is Switzerland, a small Alpine country with a wide range of hydroclimatologic conditions.

The key of the extension of the model framework is a seasonal approach, i.e., a model set up for each of the up to three distinct seasons encountered in Alpine environments: i) pluvial season, ii) accumulation season (during winter), and iii) melting season (spring and summer). The pluvial season occurs between the end of the melting season and the beginning of a new accumulation season and the streamflows are rainfall driven. It can be modelled by the original model framework, but required the definition of more robust parameter estimation methods in the context of this Thesis, particularly for the linear and nonlinear recession parameters. The extension to the melting season is newly developed in this Thesis, incorporating the earlier extension to the snow accumulation season by Schaefli et al. (2013).

A key result of all completed parameter estimation tests for pluvial regimes is the very good performance of an inverse approach based onmaximumlikelihood estimation (MLE). MLE shows outstanding results even for short series of observations and can be retained as the recommendedmethod to be used for the model framework studied in this Thesis.

The extension to the ablation (melt) season is achieved by the incorporation of themelting contribution as equivalent precipitation (sum of rainfall and snowmelt) and an ensuing increase of the streamflow producing frequency as compared to the one resulting from rainfall input alone. The amount of equivalent precipitation is calculated based on the snow accumulation from the existing model extension to winter low flows, combined with a process-based definition of seasons rather than calendar dates. A detailed analysis for all seasons for 10 selected case studies shows that the new seasonal approach yields good results for Alpine streamflow distributions, including for glacier-influenced catchments.

The improved parameter estimationmethods developed in this thesis for all dominant hydrologic seasons establish a new reference approach for regionalization, opening new perspectives for flow duration curve estimation in ungauged catchments. Other promising results are the consistency of estimatedmodel parameters with underlying physical processes and namely the observed correlation between model parameters and mean catchment elevation. This will allow the study of land use and climate changes in future model applications.

Keywords

Flow duration curves, hydrological modelling, stochastic hydrology, Alpine hydrology, recession analysis.

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