

Bayesian comparison of different rainfall depth-duration-frequency relationships

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Abstract

Depth-Duration-Frequency curves estimate the rainfall intensity patterns for various return periods and rainfall durations. An empirical model based on the Generalized Extreme Value Distribution is presented for hourly maximum rainfall, and improved by the inclusion of daily maximum rainfall, through the extremal indexes of 24 hourly and daily rainfall data. The model is then divided into two sub-models for the short and long rainfall durations. Three likelihood formulations are proposed to model and compare independence or dependence hypotheses between the different durations. Dependence is modelled using the bivariate extreme logistic distribution. The results are calculated in a Bayesian framework with a Markov Chain Monte Carlo algorithm. The application to a data series from Marseille shows an improvement of the hourly estimations thanks to the combination between hourly and daily data in the model. Moreover, results are significantly different with or without dependence hypotheses: the dependence between 24 hours and 72 hours durations is significant, and the quantile estimates are more severe in the dependence case.

Keywords

Depth-Duration-Frequency; Extreme value distributions; Bivariate extreme distributions; Extremal index; Bayesian framework

Abbreviations

DDF, Depth-Duration-Frequency; MCMC, Markov Chain Monte Carlo; GEV, Generalized Extreme Value Distribution; h, hour

1. Introduction

The rainfall intensity patterns for various return periods are required for designing hydraulic structures (dams, levees, drainage systems, bridges, etc.) or for flood mapping and zoning. The objective of the rainfall depth-duration-frequency (DDF) curves is to estimate the maximum amount of rainfall for any duration and return period. This frequency analysis uses annual or seasonal maximum series, or independent values above a high threshold selected for different durations. If each duration is treated separately, contradictions between rainfall estimates can occur. DDF analysis takes into account the different durations in a single study, and prevents curves from intersecting.

The first relationship goes back as early as 1932 (Bernard, 1932). The classical approach for building DDF curves has three steps (Chow et al., 1988). In the first step, a probability distribution function is fitted to each duration sample. In the second step, the quantiles of several return periods T are calculated using the estimated distribution function from step one. Lastly, the DDF curves are determined by fitting a parametric equation for each return period, using regression techniques between the quantile estimates and the duration. The disadvantages of this procedure are the need to have a large number of parameters, and the calculation of a regression based on dependent values (since the estimated quantiles come from the same observed series, but aggregated into different time scales). There are other more consistent approaches, using for example an extreme value distribution (e.g. Koutsoyiannis et al. (1998)).

Several empirical models have been proposed (see Garcia-Bartual and Schneider, 2001 for a review). More recently, some approaches have been derived from a multifractal process (Burlando and Rosso, 1996; de Lima and Grasman, 1999; Veneziano and Furcolo, 2002; Borga et al., 2005). All these approaches need fewer parameters than the classical one, but the dependence problem remains. In section 2, two models are presented: an empirical classical model and an improved empirical model including a relation between the daily and 24 hourly maximum rainfall distributions. Section 3 presents theoretical and practical methods for estimating model parameters, quantiles and confidence intervals in a

