Journal of Hydrology: Regional Studies 4 (2015) 123–133

Contents lists available at ScienceDirect

Journal of Hydrology: Regional Studies

journal homepage: www.elsevier.com/locate/ejrh

Multiparameter probability distributions for heavy rainfall modeling in extreme southern Brazil

Samuel Beskow [a,*], Tamara L. Caldeira [b], Carlos Rogério de Mello [c], Lessandro C. Faria [a], Hugo Alexandre S. Guedes [d]

[a] *Center of Technological Development/Water Resources Engineering, Federal University of Pelotas, 01 Gomes Carneiro Street, CEP 96010-610 Pelotas, RS, Brazil*
[b] *Center of Technological Development/Post-Graduate Program in Water Resources, Federal University of Pelotas, 01 Gomes Carneiro Street, CEP 96010-610, Pelotas, RS, Brazil*
[c] *Soil and Water Engineering Group, Federal University of Lavras, C.P. 3037, CEP 37200-000 Lavras, MG, Brazil*
[d] *Engineering Center/Civil Engineering, Federal University of Pelotas, 987 Benjamin Constant Street, CEP 96010-020 Pelotas, RS, Brazil*

ARTICLE INFO

Article history:
Received 13 October 2014
Received in revised form 15 May 2015
Accepted 8 June 2015
Available online 23 June 2015

Keywords:
Extreme rainfall events
Probabilistic modeling
Kappa
GEV

ABSTRACT

Study region: The study was conducted in the Rio Grande do Sul state – Brazil.
Study focus: Studies about heavy rainfall events are crucial for proper flood management in river basins and for the design of hydraulic infrastructure. In Brazil, the lack of runoff monitoring is evident, therefore, designers commonly use rainfall intensity–duration–frequency (IDF) relationships to derive streamflow-related information. In order to aid the adjustment of IDF relationships, the probabilistic modeling of extreme rainfall is often employed. The objective of this study was to evaluate whether the GEV and Kappa multiparameter probability distributions have more satisfying performance than traditional two-parameter distributions such as Gumbel and Log-Normal in the modeling of extreme rainfall events in southern Brazil. Such distributions were adjusted by the L-moments method and the goodness-of-fit was verified by the Kolmogorov–Smirnov, Chi-Square, Filliben and Anderson–Darling tests.
New hydrological insights for the region: The Anderson–Darling and Filliben tests were the most restrictive in this study. Based on the Anderson–Darling test, it was found that the Kappa distribution presented the best performance, followed by the GEV. This finding provides evidence that these multiparameter distributions result, for the region of study, in greater accuracy for the generation of intensity–duration–frequency curves and the prediction of peak streamflows and design hydrographs. As a result, this finding can support the design of hydraulic structures and flood management in river basins.

* Corresponding author. Tel.: +55 5339211240.
E-mail addresses: samuel.beskow@ufpel.edu.br (S. Beskow), tamaraleitzkecaldeira@gmail.com (T.L. Caldeira), crmello@deg.ufla.br (C.R. de Mello), lessandro.faria@ufpel.edu.br (L.C. Faria), hugo.guedes@ufpel.edu.br (H.A.S. Guedes).

http://dx.doi.org/10.1016/j.ejrh.2015.06.007

1. Introduction

Studies of extreme rainfall events have great relevance for water resources management, as they provide insight into the understanding of the hydrological behavior of a given watershed under the flooding point of view. In this context, engineers commonly need to establish flood control techniques and to estimate the peak streamflows or hydrographs for the design of hydraulic structures. Because it is more frequent the existence of rainfall monitoring, a good option for ungauged watersheds is to estimate a design precipitation or a design hyetograph and then, using rainfall-runoff modeling, to derive the aforementioned streamflow characteristics.

The rainfall monitoring enables registration of its temporal variability and the probabilistic modeling of extreme values, thus making it possible to estimate intensity–duration–frequency (IDF) curves. Such curves can be employed in ungauged watersheds to estimate peak streamflows through empirical models and to derive design hyetographs and hydrographs according to well-known hydrologic methods.

Daily or sub-daily rainfall data sets are used for the modeling of heavy rainfall events, the latter being the most suitable, because it allows the determination of rainfall intensities associated with different durations. However, due to the lack of sub-daily data, studies conducted in Brazil have commonly applied daily rainfall data sets through annual maximum daily rainfall series (Silva and Clarke, 2004; Souza et al., 2012; Aragão et al., 2013; Franco et al., 2014; Caldeira et al., 2015).

There are numerous probabilistic models applied to continuous random variables, such as annual maximum daily rainfall. In Brazil, the fit of more simplified theoretical probability models has been commonly observed, such as 2 and 3 parameter Log-Normal distribution, and Asymptotic Extreme Value Type I, also known as Gumbel (Silva et al., 2002; Sansigolo, 2008; Santos et al., 2009; Back et al., 2011; Souza et al., 2012; Mello and Viola, 2013; Caldeira et al., 2015). However, several studies associated with heavy rainfall events have sought also evaluate other probability distributions, such as the 2-parameter Gamma (Franco et al., 2014), Generalized Extreme Value (Durrans and Kirby, 2004; Nadarajah and Choi, 2007; Blain and Camargo, 2012; Blain and Meschiatti, 2014), Kappa (Parida, 1999; Park and Jung, 2002; Norbiato et al., 2007; Ahmad et al., 2013; Blain and Meschiatti, 2014), Wakeby (Park et al., 2001; Blain and Meschiatti, 2014), Generalized Logistic (Norbiato et al., 2007; Hailegeorgis et al., 2013; Rahman et al., 2013) and Generalized Pareto (Hailegeorgis et al., 2013; Rahman et al., 2013).

Nevertheless, a continuous random variable can be represented by more than a probabilistic model. The choice of the model that best fits the data series is performed by nonparametric tests seeking to evaluate relationship between the observed and theoretical frequencies. In hydrology, it can be highlighted the goodness-of-fit tests of Kolmogorov–Smirnov, Chi-Square, Filliben and Anderson–Darling (Sansigolo, 2008; Ben-Zvi, 2009; Back et al., 2011; Franco et al., 2014).

The methodology of statistical inference (estimation of parameters) exerts influence upon the adjustment quality of a probabilistic model. There are various methods of statistical inference such as the method of moments, maximum likelihood and L-moments. Naghettini and Pinto (2007) report that the method of moments is the simplest, but can produce low quality estimators, especially for probability distributions with three or more parameters, when compared to the maximum likelihood method. This, in turn, may be considered more efficient than the previous, yielding estimators of lower variance, however, it involves equations which are generally nonlinear and implicit. According to these authors, the L-moments method results in parameter estimators comparable in quality to those produced by the maximum likelihood method, being frequently more accurate for small samples which are commonly used in hydrologic studies.

Given the above, the objectives of this study were: (i) to evaluate the performance of multiparameter probability distributions versus those commonly used in hydrologic studies applied to the modeling of extreme rainfall events in the extreme south of Brazil; and (ii) to define the most suitable probabilistic model, based on the analysis of goodness-of-fit tests, for the random variable evaluated in this study.