Journal of Hydrology (2006) 330, 329–339

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

Data-based comparison of seasonality-based regional flood frequency methods

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Received 6 October 2005; received in revised form 6 March 2006; accepted 26 March 2006

KEYWORDS
Flood seasonality;
Regionalization;
Regression;
Quantile;
Regional flood frequency analysis;
Spring flood;
Peaks-over-threshold;
Jackknife

Summary During the last 10 years a growing number of regional flood frequency estimation studies have used flood seasonality descriptors for delineating hydrologically homogeneous regions. Seasonality of floods reflects a complex catchment's hydrologic response to flood producing processes. Due to the high accuracy and robustness of flood date data, the use of flood seasonality indices became an attractive alternative to traditional regionalization approaches for the delineation of homogeneous regions, a key step in any regionalization study. This paper presents a data-based comparison of three flood seasonality regionalization methods. The methods are applied to a set of catchments in the province of Québec (Canada). A jack-knife procedure is used to assess the performance of the methods in regional quantile estimation. The results are compared to those obtained from a traditional regionalization approach based on catchment physiographic similarities, and to the results from a scenario where information available in all catchments is used in the analysis. The seasonality method based on the peaks-over-threshold approach was concluded to lead to best results.

Introduction and review

Regional flood frequency analysis is usually applied when no or insufficient local data are available for a reliable estimation of flood quantiles for the required return period. It usually involves two main steps: the delineation of groups or regions of homogeneous basins and the application of a

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0022-1694/$ - see front matter
doi:10.1016/j.jhydrol.2006.03.023

regional estimation method within each delineated region to assess the probability of exceedance of a flood event for a site of interest. Homogeneous regions can be defined as geographically contiguous regions, geographically non-contiguous regions, or as hydrological neighbourhoods (Ouarda et al., 2001). The identification of hydrologically homogeneous regions was traditionally based on grouping catchments according to physiographic similarity (Mosley, 1981; Wiltshire, 1985, 1986; Acreman and Sinclair, 1986; Ando, 1990; Pearson, 1991; GREHYS, 1996; FEH (Flood Estimation Handbook), 1999; Chokmani and Ouarda, 2004).

Another regionalization approach that has been recently gaining increased popularity among hydrologists is based on the similarity in flood seasonality. In these seasonal regional models, the delineation of homogeneous regions is based on the seasonal behaviour of flood flows in the various stations. The seasonal partitioning of the year in each station (number of significant seasons, dates of beginning and end of each season) is used to identify groups of basins with similar seasonal behaviour. The main advantage of this approach is that flood seasonality is described using flood date data, which are practically error-free and more robust than flood magnitude data since flood date data are bounded. The use of flood seasonality information to delineate homogeneous hydrological regions allows also to separate mixed-distribution floods. These floods are usually generated by different mechanisms, such as, in northern latitudes, spring floods generated by snow melt and summer/fall floods generated by intense rainfall. Flood seasonality can also be used in other applications in the field of water resources, such as reservoir management, flood forecasting and floodplain protection.

Previous research in this direction include the work of Bayliss and Jones (1993) who described flood seasonality in Great Britain by seasonality indices derived from directional statistics. Ouarda et al. (1993) and Ashkar et al. (1993) proposed two different forms of a graphical procedure for determining flood seasons from peaks-over-threshold data. This procedure consists of plotting the cumulative mean number of exceedances per year against the time for a number of increasing base levels. The behaviour of these plots (change of slope, piecewise linearity, etc.) indicates the significant seasons for each station. According to this procedure the authors partitioned gauged sites in the provinces of Québec and New Brunswick, Canada, into homogeneous groups with similar flood seasonality characteristics. Reed (1994) suggested that flood seasonality measures can be used as a means of defining catchment similarity. Magilligan and Graber (1996) suggested to use contour maps of mean day and variance of flood occurrences to depict the flood regime. They constructed these contour maps for New England floods, USA, and analysed the relationships between physiographic controls and flood timing using multiple regression models.

Burn (1997) applied flood seasonality descriptors in a neighbourhood-based regionalization study in the Canadian prairies. The approach proposed by Burn (1997) uses the information derived from flood magnitudes for the examination of the homogeneity of flood regions as opposed to using this information to form the regions. He demonstrated that such regionalization resulted in effective estimation of flood quantiles. The FEH (Flood Estimation Handbook) (1999) explored the effect of urbanization on the seasonality of floods in a regional framework. Merz et al. (1999) discussed the seasonality of flood flows in Austria and identified several flood regimes. Castellarin et al. (2001) combined flood and rainfall seasonality descriptors and basin relative permeability in a regional model for ungauged basins in Northern Italy. Cunderlik and Burn (2002a) presented a focused pooling approach that is based on flood regime information and which depicts both flood seasonal pattern and flood regularity. The authors explored the sensitivity of the seasonality descriptor to the record length and the length of overlapping period and showed that the information that is captured in flood seasonality is sufficient for effective estimation of flood quantiles.

Cunderlik and Burn (2002b) explored the appropriateness of substituting rainfall regime for flood regime in regional flood frequency analysis, to take advantage of the spatial and temporal abundance of rainfall data. The authors used two different approaches based on directional statistics to describe rainfall regime similarity. Thompson (1999) and Hodgkins et al. (2003) focused on changes in the timing of peak flow dates and in the seasonality of floods and precipitations in various parts of the world. Cunderlik et al. (2004a) proposed a method based on directional statistics, which tests the significance of flood seasons by comparing the observed variability of flood occurrences with the theoretical flood variability in a nonseasonal model. The authors also addressed the uncertainty resulting from sampling variability by quantifying the probability associated with the identified flood seasons. The method was applied for the determination of the main flood seasonality types in Great Britain. Cunderlik et al. (2004b) in a simulation based study, focused on the uncertainty involved in the use of seasonal models based either on directional statistics or on the monthly relative frequencies of flood occurrence. McCuen and Beighley (2003) demonstrated the need to estimate design floods from seasonal rather than annual maximum discharge data and proposed two methods for the estimation of missing below-threshold discharge data in seasonal models. Cunderlik and Burn (2006a) developed a site-focused, non-parametric test of regional homogeneity based on flood seasonality information. In contrast to other tests, this test does not use flood magnitude data, avoids pre-definition of a fixed regional distribution, and is focused on a site of interest and a target return period. Finally Cunderlik and Burn (2006b) proposed a new pooling approach that takes into consideration the sampling variability of flood seasonality measures used as pooling variables. A nonparametric resampling technique is used to estimate the sampling variability for the target site, as well as for every site that is a potential member of the pooling group for the target site. The variability is then quantified by Mahalanobis distance ellipses defined for various confidence intervals. The confidence intervals can be related to regional homogeneity, which allows the target degree of regional homogeneity to be set in advance.

Despite the increasing interest in the rational identification of flood seasons and in the use of flood seasonality to identify homogeneous hydrological regions for regional flood frequency analysis, no studies have focused on the comparison of the various approaches that have been proposed in the literature. The main objective of this study is