Spatial Variability and Cartography of Maximum Annual Daily Rainfall under Different Return Periods in Northern Algeria

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Abstract: The estimation of precipitation quantiles has always been an area of great importance to meteorologists, hydrologists, planners and managers of hydrotechnical infrastructures. In many cases, it is necessary to estimate the values relating to extreme events for the sites where there is little or no measurement, as well as their return periods. A statistical approach is the most used in such cases. It aims to find the probability distribution that best fits the maximum daily rainfall values. In our study, 231 rainfall stations were used to regionalize and find the best distribution for modeling the maximum daily rainfall in Northern Algeria. The L-moments method was used to perform a regionalization based on discordance criteria and homogeneity test. It gave rise to twelve homogeneous regions in terms of L-Coefficient of variation (L-CV), L-Skewness (L-CS) and L-Kurtosis (L-CK). This same technique allowed us to select the regional probability distribution for each group using the Z statistic. The generalized extreme values distribution (GEV) was selected to model the maximum daily rainfall of 10 groups located in the north of the steppe region and the generalized logistic distribution (GLO) for groups representing the steppes of Central and Western Algeria. The study of uncertainty by the bias and RMSE showed that the regional approach is acceptable. We have also developed maximum daily rainfall maps for 2, 5, 10, 20, 50 and 100 years return periods. We relied on a network of 255 rainfall stations. The spatial variability of quantiles was evaluated by semi-variograms. All rainfall frequency models have a spatial dependence with an exponential model adjusted to the experimental semi-variograms. The parameters of the fitted semi-variogram for different return periods are similar, throughout, while the nugget is more important for high return periods. Maximum daily rainfall increases from South to North and from West to East, and is more significant in the coastal areas of eastern Algeria where it exceeds 170 mm for a return period of 100 years. However, it does not exceed 50 mm in the highlands of the west.

Keywords: Annual maximum daily rainfall; Regionalisation; L-moments; Mapping; Northern Algeria

Introduction

The knowledge of maximum daily rainfall and its return period is an important topic in the fields of hydraulic engineering, soil conservation, flood protection in urban areas and the protection of human life and public and private properties. Flooding hazards can be attributed to one or a combination of several factors (rainfall, geology, topography ...). Extreme rainfall or heavy rain falling in a short period of time can result in flash flooding. Similarly, long periods of heavy rain can
cause flooding. The analysis of trends and climate extreme variability has recently received increased attention. However, the availability of good quality daily data over long periods of time as is required for the analysis of extreme variations has been the major obstacle (Easterling et al. 2000).

Recent flood events around the world let us inquire whether these events were the result of climate change or other factors. Floods are the most common natural disasters in the world. Over 500 million people are affected by floods in the world. In Europe, for example, floods caused 700 deaths and economic losses estimated at 25 billion Euros between 1998 and 2006. During 1988-97, floods accounted for about one-third of all natural catastrophes, caused more than half of all deaths from catastrophes and were responsible for one-third of overall economic losses from catastrophes (FAO 2002).

In Algeria, floods caused 87 fatalities and affected 1500 families and 31 municipalities between September and October 2008. Flooding in the region of Ghardaia, October 2008, resulted in 43 fatalities and material damage estimated at almost €250 million.

The floods that affected Bab El Oued district (Algiers) in 2001 caused 733 casualties and left some 30,000 people homeless, in addition to causing significant material damage. In October 1994, floods across the country resulted in 60 fatalities and left hundreds missing during 10 days of bad weather. These figures show the seriousness of this phenomenon.

Since the 1970s, rainfall has decreased in Algeria and over the Mediterranean countries (Meddi and Hubert 2003; Meddi et al. 2010; Sebbar et al. 2011; Yeslirmak et al. 2008; Costa et al. 2009; Caloiero et al. 2009). Meddi et al. (2014) also found a decrease in the number of rainy days per year, above different thresholds (5, 10, 20 and 30 mm).

The behavior of maxima can be described by the three distributions of maxima, i.e.: Gumbel, Fréchet and the negative Weibull distribution, as suggested by Fisher and Tippett (1928). Early studies of the distribution of maximum values were probably made by Fuller (Nadarajah 2005). Since then, many researchers have studied the distribution of extreme values of precipitation in different parts of the world: Oyebande (1982) in Nigeria, Rakhecha et al. (1998) in India, Withers et al. (2000) in New Zealand, Crisci et al. (2002) in Italy, Koutsoyiannis and Parida (1999) in Greece, Naghavi and Fang (1993), Segal et al. (2001) et Nadarajah (2005) in the United States of America, Kieffer and Bois (1997), Neppel et al. (2001), Mora et al. (2005) in France.

In Algeria, to study the extreme values of rainfall and flow rates, the Gumbel distribution is commonly used. These studies are used for the dimensioning of hydraulic structures (dams, dikes, canals...) that are used to protect and at the same time ensure the supply of drinking water to the population. The projection of structures and the preparation of flood security plans require frequency values of $10^{-2}$ to $10^{-4}$, generally based on the importance of the structure. The Gumbel (Eq. 2) distribution has long been the most widely used model to estimate quantiles. The first study focused on extreme rainfall mapping in the region of Algiers (Aissani and Laborde 1983). They used the Gumbel distribution without the critical study to choose between the different distributions able to model the maximum daily rainfall. In the second work, Mouhous (1997) conducted the automatic mapping of decadal extreme rainfall in the northern of Algeria using the Gumbel model to calculate rainfall frequency without maximum daily rainfall regionalization. Both studies were conducted without regionalization of maximum daily rainfall.

Koutsoyiannis (2004) showed that the application of the Gumbel distribution can lead to a misestimation of risks by an underestimation of the greatest extremes of rainfall, especially when we have a series of a few decades that may not have the same distribution as the true distribution, suggesting that the Gumbel distribution is the right model, while it is not the case.

Many researchers prefer to use the generalized extreme value (GEV) distribution (Eq.1) than the Gumbel distribution to model the annual maximum daily rainfall (Wilks 1993; Chaouche et al. 2002; Koutsoyiannis 2004; Onibon et al. 2004; Bacro and Chaouche 2006). There is a large difference between the quantiles estimated by the Gumbel distribution and the quantiles estimated by the generalized extreme value distribution (Muller 2006). For a given frequency, the quantiles of a generalized extreme value distribution can be