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Research paper

Time distribution of heavy rainfall events in south west of Iran

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ABSTRACT

Accurate knowledge of rainfall time distribution is a fundamental issue in many Meteorological-Hydrological studies such as using the information of the surface runoff in the design of the hydraulic structures, flood control and risk management, and river engineering studies. Since the main largest dams of Iran are in the south-west of the country (i.e. South Zagros), this research investigates the temporal rainfall distribution based on an analytical numerical method to increase the accuracy of hydrological studies in Iran. The United States Soil Conservation Service (SCS) estimated the temporal rainfall distribution in various forms. Hydrology studies usually utilize the same distribution functions in other areas of the world including Iran due to the lack of sufficient observation data. However, we first used Weather Research Forecasting (WRF) model to achieve the simulated rainfall results of the selected storms on south west of Iran in this research. Then, a three-parametric Logistic function was fitted to the rainfall data in order to compute the temporal rainfall distribution. The domain of the WRF model is 30.5N–34N and 47.5E–52.5E with a resolution of 0.08 degree in latitude and longitude. We selected 35 heavy storms based on the observed rainfall data set to simulate with the WRF Model. Storm events were scrutinized independently from each other and the best analytical three-parametric logistic function was fitted for each grid point. The results show that the value of the coefficient a of the logistic function, which indicates rainfall intensity, varies from the minimum of 0.14 to the maximum of 0.7. Furthermore, the values of the coefficient $B$of the logistic function, which indicates rain delay of grid points from start time of rainfall, vary from 1.6 in south-west and east to more than 8 in north and central parts of the studied area. In addition, values of rainfall intensities are lower in south west of IRAN than those of observed or proposed by the SCS values in the US.

1. Introduction

Determining of rainfall parameters such as the rainfall pattern is essential to estimate the amount of the runoff and flood management. Rainfall time distribution patterns show variations in the rain intensity during rainfall. Since the flood volume and its peak time depend on the rain intensity, the rainfall pattern is beneficial in managing water resources and passing flood in urban basins, and designing of the control structures.

Several approaches were proposed to determine the temporal distribution of rainfall. Some researchers have presented theoretical methods using mathematical relations. Others have achieved temporal rainfall patterns for particular regions by experimental methods and real data. Huff (1967) extracted temporal rainfall distribution for 262 heavy storms over central Illinois using rain data of 49 rain gauges. They introduced time distribution models based on probability of the greatest part of precipitation occurred within each of the first to fourth quartiles. Pilgrim and Cordery (1975) offered temporal rainfall distribution pattern by selection of intense rainfalls with different time bases in Sydney of Australia. They mapped dimensionless cumulative amounts of intense rainfalls and demonstrated their average curve as the temporal distribution pattern of rainfall. Shaw et al. (1984) analyzed statistically 1400 storms which are recorded throughout the state of Virginia. They concluded that the temporal distribution of Virginia storms differed significantly from the commonly recognized distribution curves such as the Huff quartile curves and the Soil Conservation Service (SCS) curves. In addition, the Virginia curves showed a shorter time to the peak rainfall and a lower rate of increase near the mid-portion of the storm duration. U. S. Soil Conservation Service (1973) has worked on the method for predicting storm runoff from array of the storm events. The SCS method presented the 24-h Type I, IA, II, and IIA rainfall time

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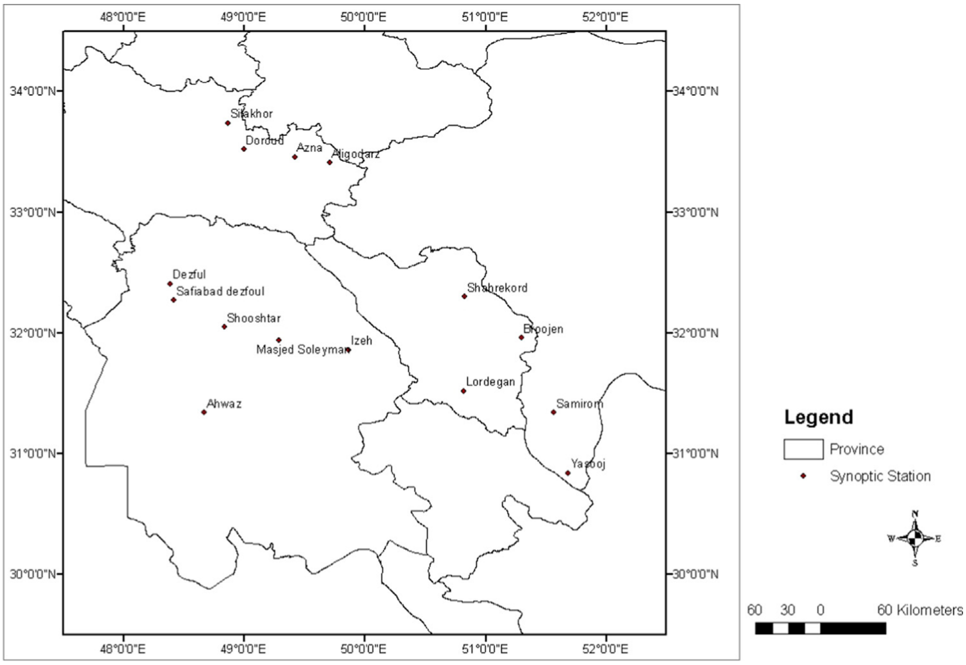

Fig. 1. Map of south west of Iran showing the synoptic rainfall stations.

distributions. Soon after, Technical Release 55 (TR-55) (1986) presented a unit graph approach to predict peak discharge according to a 24-h synthetic storm. However, this method should be developed elsewhere based on local storms distribution. Sen and Eljadid (1999) identified the most suitable probability distribution function for the monthly rainfall records over Libya with the gamma distribution. To determine the regional rainfall characteristics, they prepared maps of "shape" and "scale" parameters at points without a station. Therefore, it is possible to make predictions for any required amount of rainfall probability occurrence. Guo and Hargadin (2008) analyzed and compared a 57-year hourly rainfall data recorded in Denver, Colorado with the SCS 24-h Type I and II rainfall curves. The comparison indicated that the design rainfall curves can be constructed using the low enveloping curve for the leading portion, the high enveloping curve for the tail portion, and a sharp rise between leading and trail portions. Mojaradi Gilan et al. (2010) determined temporal rainfall variability patterns in Alvand watershed of Iran. Since Alvand patterns and SCS type patterns are nonsimilar, it was not recommended to apply 24 h rainfall SCS type patterns to Alvand watershed at all. Haerter et al. (2010) used observational precipitation data at a temporal resolution of 5 min from six stations in Germany. They obtained scaling relations of the probability distributions of precipitation intensity with temperature and time scale. Temporally averaged at the daily time scale, increases in precipitation intensity below the Clausius–Clapeyron rate were found with systematically lower increases at higher temperatures. Back (2011) determined the time distribution pattern of heavy rain events in Urussanga, Santa Catarina State, Brazil. Based on the analysis of rainfall data, the most frequent heavy rainfall events were type I (42.4%) followed by type II (31.1%) which were occurred more frequently during the summer, and type III (18.9 %) and type IV (17.6 %), which were occurred throughout the year. Caballero and Rahman (2013) regionalized the rainfall temporal patterns in New South Wales, Australia using data from 86 pluviograph. They applied the Monte Carlo Simulation technique to obtain the flood design. It has been found that the use of at-site and regional temporal patterns can give up to about 10% differences in flood quantile estimates.

The above studies computed the time distribution patterns of rainfall events only in the specific regions and expert analysis is required to use them for other areas including Iran. Additionally, the time distribution patterns of heavy rainfall events have not been investigated much in Iran. Therefore, this paper have selected 35 heavy storms based on the observed rainfall data set in south west of Iran to find the time distribution of the heavy rainfall events.

The organization of this paper is as follows: Section 2 explains our methodology, including selecting heavy storm events, simulating the storm events by WRF model and calculating time distribution of rainfall by the logistic function. Section 3 presents experimental results. Conclusion and suggestions for the further study are given in Section 4.

2. Materials and methods

The proposed framework includes three stages as follows:

1. Selecting heavy storm events in the south west of Iran.
2. Simulating selected storm events by WRF model.
3. Computing temporal distribution of rainfall using WRF simulated rainfall data and a logistic function.

The following subsections provide a detailed description of the main components.

2.1. Selection of synoptic rainfall events

This study employed observation rain data set of the synoptic stations (see Fig. 1) which was received from 2001 to 2010 by the Iranian meteorological organization (IRIMO). First, IRIMO controlled the quality of data set. Next, we selected the storms with precipitation of over 50 mm to simulate events in all grid points of WRF model (see Section 2.2.), so that the precipitation interval of the model was three hours.