Spatial-Temporal Modeling of Thunderstorm Occurrence in the Northwest Iran

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Extended Abstract

Introduction

Thunderstorms are formed by overheating the earth's surface in air masses or in the weather fronts especially cold front (Kaviani and Alijani, 1991). These storms are part of climatic destructive phenomenon that cause irreparable damage as hail, heavy rainfall and thunders to facilities of farms and houses every year. Thus, it is necessary to study this phenomenon. The climatic phenomena such as thunderstorms, as random phenomena, are not exactly predictable and can gain useful information by monitoring them, that this is possible through the laws of probability. Markov chain is a common method for modeling random phenomena (Wilks, 2006). This model is one of the statistical methods to examine the temporal relationship between the various climatic phenomena and it is the most common method to determine the frequency of climatic phenomena sequences. In this method, the probability of occurrence of a climate state is projected at time t based on its condition at the time before (t-1) (Alizadeh, 2001). This model is widely used in various fields including atmospheric sciences. In recent decades, climate researchers have used this model in various fields such as rainfall, drought, thunderstorm, wind speed and solar radiation. Thunderstorms are known as one of the most important atmospheric phenomena, due to the obvious climatic function and imposition of natural and human catastrophic effects. Many scholars and researchers pay attention to it in the various branches of science. The aim of this study is to evaluate the occurrence probability and return period of thunderstorm using Markov chain model and its spatial analysis in the Northwest Iran.

Materials and Methods

For analysis of spatial-temporal modeling of thunderstorm occurrence in the Northwest Iran we have used meteorological data for 19 synoptic stations during the period 2000-2015. Markov chain models are including stochastic processes that are widely used in discrete time series modeling. Time dependence of random variables is expressed through autocorrelation coefficient or transition probability matrix (Ashgartousi et al., 2003). Transition probability matrix is a square matrix, depending on its number of states that includes the number of possible *n* combinations of the transition probability from one state to another. The first order Markov

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chain is the main form of the Markov chain which consists of a discrete time series which the behavior of the series in the next time step depends on present not on past time steps. If possible states for the time series of thunderstorm days are considered in normal days (0) and thunderstorm days (1), the state in the next step could be between of 0 and 1. We have calculated the matrix elements and transition probabilities of some important characteristics of the data:

a) The frequency of occurrence of two states and the change of the states were calculated and transition frequency matrix was determined. b) The transition probability matrix was calculated using the maximum likelihood estimation method. c) After determining the transition probability, it is necessary to examine the fit of Markov chain model on data series. To this purpose, the chi-square test (χ^2) is used. d) The persistent probability for each state was calculated using transition probability values. e) The possibility of occurrence of the period of 1-5 days was predicted. f) The frequency of occurrence of the period of 1-10 dusty days was estimated. g) The n-day return period was calculated.

Results and Discussion

To examine the sequence of thunderstorm days in the Northwest Iran, at first the frequency of normal and Thunderstorm days were calculated. The results show that in April, the highest frequency of days with thunderstorms is in center, in May in northwestern areas and in June and July in central areas, can be seen in the northwest. The lowest frequency can also be seen in the southern parts of the study area. Frequency and transition probability matrix was calculated for time series of thunderstorm days. Then, the fitness of the two- state first order Markov chain model were studied using χ^2 test and the results showed that the states frequency follow a two-state Markov chain. In order to predict the thunderstorm period, at first, the frequency of *n* days' period of thunderstorm days was projected in April, May, June and July for stations. The results show that by increasing the duration of period, the frequency of the dusty days is reduced.

The estimate of *n* day continuity of thunderstorm days represents the abilities of the Markov chain model. In April, the occurrence of two-days in the center and west part of study area is more possible. In May, there is the highest frequency of thunderstorm days, the probability of two- days increased to 24%. In June, the average probability of two-days is 23%. The probability of three-days in April reduced an average of 6%. In May and June, the probability is about 10%. In these months, the probability of three-days has reached 15% in North and Northeast. In July, the probability of three-days has reduced; while, in the western part it is estimated up to 14%. Return period of one-day in all stations is on average 1.5. This means that every 1.5 days, a one-day will be in the Northwest Iran. For increase in duration of thunderstorm, the return period increases, it means that it takes a long time of five-thunderstorm days again. Spatial distribution of occurrence probability of thunderstorm days in the long-term (persistent probability) showed that in April, the lowest probability of thunderstorm is in the Northeast and the highest probability is in the center. In May and June, the lowest probability is in the southern parts and the highest probability in the North and Northwest. In July, the lowest probability is in the South and Northeast and the highest in the West and Northwest. In general, the probability of days with thunderstorm in the south and northeast is less than other areas.

Conclusion

The results of this research show that in all stations, frequency of normal days is more than the days with thunderstorm. The highest frequency of days with thunderstorms in April is in center, in May in northwest and central areas and in June and July in the northwest. The estimate of 1-10 days continuity showed that by an increase in the duration of period, frequency of dusty days. The probability of the occurrence of two and three-days is low in the South and Northeast and high in center and Northwest. Return period of one-day on all stations and in all months is 1.5, but by increasing duration of dust, its return period increases exponentially. The spatial distribution of persistent probability matrix shows that the occurrence of thunderstorm in center, North and Northwest is more. In general, understanding of this phenomenon and its probability is important for implementation of prevention programs and management plans to deal with this hazard in critical areas.

Keywords: day with thunderstorm, Markov chain, occurrence probability, return period, Northwest Iran.