Spatial Autocorrelation of Annual Frequency of Heavy Rainfalls in Caspian Region

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Extended abstract

Introduction

Precipitation is considered as one of the most important climate elements with high temporal-spatial variations. The variable can affect different environmental aspects represented through several different behavioral forms in extreme precipitation. Heavy and extreme rainfalls can occur in the form of flashfloods and usually in draught conditions with considerable negative consequences on human-environment. Therefore, the study of this type of precipitation in the area is an area suitable for agricultural activities. Recognition of such patterns can determine the success in environmental management as well as certainty in resources planning. There is considerable heavy and super heavy precipitation in coastal regions of Caspian Sea, Iran, especially in eastern areas. Thus, understanding the spatial auto-correlation of such a phenomenon can facilitate environmental planning and the reduction of vulnerability to increase adaptability with such a disaster.

Materials and methods

In order to analyze the auto-correlation of the sum of annual frequency of heavy and super heavy precipitations of this region, we examined the 90-95, 95-99 and 99 percentiles of precipitation for each pixel of the map. Accordingly, the data were gathered from 385 stations including synoptic, climatology, and rain gauge stations during the time period from 1966 to 2016. At first, the frequency of annually heavy and super heavy precipitation was plotted in the Surfer software. We have used spatial statistics techniques (global Moran index (1), local Moran (2), and Gi* index (3)) to analyze spatial auto-correlation features.

$$I = \frac{n \sum_{i=1}^{n} \sum_{i=1}^{n} w_{ij} z_i z_j}{s_o \sum_{i=1}^{n} z_i^2} \quad (1)$$

$$I_i = \frac{x_i - \bar{x}}{s_i^2} \sum_{j=1, j\neq i}^{n} w_{i,j}(x_i - \bar{x}) \quad s_i^2 = \frac{\sum_{j=1, j\neq i}^{n} w_{i,j}}{n-1} - \bar{x}^2 \quad (2)$$

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$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j}x_j - \bar{x}\sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{\left[n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}} \quad \bar{x} = \frac{\sum_{j=1}^{n} x_j}{n} \quad S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - (\bar{x})^2} \tag{3}$$

In order to investigate the relationship between spatial factors (latitude, longitude, slope and gradient) with the annual frequency of heavy and super heavy precipitation, we used the ArcGIS spatial analyst using the Digital Elevation Model (DEM) for this reign. Finally, sampling for all pixel points in the interpolation of daily rainfall data was calculated bassed on the following steps: Extracting altitudes, slopes and geographic directions of the subsurface points from the digital elevation model, the slope and the direction of slope were obtained during the extraction-sample steps. Then, the connection of the descriptive table of the layers with the elevation, slope and geographic directions of the slope were obtained for the points. In the last step, the relationship between the spatial factors and annual precipitation frequency was calculated using general Moran multivariate statistics (4).

$$I_{kl} = \frac{z_k\ w_{zl}}{n} \qquad z_k = \frac{\left[x_k - \overline{x_k}\right]}{\sigma_k}\ , \qquad z_l = \frac{\left[x_l - \overline{x_{kl}}\right]}{\sigma_l} \tag{4}$$

Results and discussion

Study of spatial relationships in order to recognize spatial distribution and spatial auto-correlation is one of the best methods for recognizing the spatial behavior of extreme rains. The purpose of this study is to determine the spatial pattern of the total annual precipitation frequency (90-95, 95-99 and 99 percentile of precipitation) using the spatial statistics techniques. Accordingly, 385 stations (synoptic, climatology, and rain gauge of Islamic Republic Organization of Meteorology, and rain gauge of the Ministry of Power) were studied during the time period from 1966 to 2016. The results of the present study showed that the dominant behavior in total annual frequency of precipitation in the study region followed a cluster pattern in three groups. The patterns indicated that the global Moran index is above 0.9, which indicates a statistical significance of this coefficient at a confidence level of 99%. Frequency maps of the annual occurrence of extreme precipitation represent that the highest occurrence of these precipitations is in the first order of the third group and then the first group of precipitation and the second group of precipitation is less in this respect. The results showed that the maximum nucleus of this precipitation was assigned in the first and second groups in the central and western areas, and in the third group in the eastern regions. This also shows the influence of the third group in this area. Positive and negative auto-correlations of spatial clusters have showed the impact of the Alborz Mountains Systems in different parts of the Caspian region. On the first and second thresholds, most cluster patterns of positive auto-correlations are located in the central and western parts. The third threshold as most positive auto-correlations is located in the eastern and central parts of the Caspian region. The negative correlation patterns were observed in the first and second groups in the eastern parts and the third group in the central and southwestern regions of the district. The G* test approved the frequency of clusters with high and low values.

Conclusion

In general, it can be said that the Caspian region is more affected by the precipitation of the third and the first group. This covers a large area of this region, especially in the western and central parts due to the frequency of occurrence of this type of precipitation in this area. The analysis of spatial dispersion and spatial relationships of this phenomenon can be effective in identifying the areas where flooding is greater and this can be used for planning environmental hazards to reduce vulnerability and increasing adaptability.

Keywords: heavy and super heavy precipitation, annual frequency, Spatial Analysis, Moran and G* Index, Caspian region.