DOI:10.28974/idojaras.2023.3.1

IDŐJÁRÁS

Quarterly Journal of the Hungarian Meteorological Service
Vol. 127, No. 3, July – September, 2023, pp. 267–283

Investigation and analysis of the Iranian autumn rainfall thickness pattern

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(Manuscript received in final form December 5, 2022)

Abstract— The purpose of this study was to investigate and analyze the trend of autumn precipitation thickness pattern in Iran. For this purpose, two environmental and atmospheric databases have been used. Environmental data is prepared and networked in two stages, in the first stage with the help of 1434 stations and in the second stage with the help of 1061 stations. Atmospheric data includes geopotential height data obtained from the National Center for Environmental Prediction and the National Center for Atmospheric Research (NCEP / NCAR). The spatial resolution of this data is 2.5 × 2.5 degrees. The thickness of the atmosphere, which is usually between 500 and 1000 hectopascals, is shown. This thickness is considered as the thickness of the whole atmosphere. The results of the autumn precipitation trend showed that although autumn precipitation on monthly and annual scales has experienced an increasing trend in most regions, in less than 5% of Iran, the upward trend has been significant. The most intense upward trend is observed in the form of spots in the central and northern parts of the Zagros Mountain, while the greatest decreasing trend has been observed in the form of cores along the Caspian coastal cities. The results of the autumn precipitation thickness pattern showed that the autumn precipitation thickness pattern is affected by deflection and instability due to high latitude cold and humid weather and low latitude hot and humid weather occurred in North Africa, in such a way that the Black Sea and the Mediterranean Sea provide the required moisture in high latitudes and the Red Sea and the Persian Gulf in low latitudes.

Key-words: precipitation, trend, atmospheric thickness, synoptic patterns, Iran

1. Introduction

Precipitation is the most vital climatic element that affects almost all aspects of life on Earth and is directly or indirectly evident and felt in various human activities. Precipitation as a random variable has many temporal and spatial variations. The climatic situation of Iran is such that in terms of latitude and penetration of subtropical high-pressure systems, in addition to low precipitation, its precipitation regime, especially spring precipitation, fluctuates sharply (*Jalali et al.,* 2019). Climate change can be studied by tracking characteristics such as the quantity, spatiotemporal pattern, and circulation patterns of climatic elements, especially temperature and precipitation. For example, precipitation as one of the basic elements of the climate, especially during the twentieth century, has increased by about 0.1% in the middle and upper latitudes of the northern hemisphere, while no change in southern hemisphere precipitation is observed (*Ventura et al*., 2002).

Due to its proximity to the abundant moisture resources of the Mediterranean Sea in the west, the Persian Gulf the Oman Sea, and the sea surface temperature moisture regions in the south, the Caspian Sea in the north, the Black Sea and the Indian Ocean in the east, our country has a relatively high impact. Therefore, the study of these effects on the amount of precipitation in the country has a key role in recognizing precipitation fluctuations and predicting precipitation (*Rezaei Banafsheh et al*., 2010). One of the climatic characteristics of each region is the amount of precipitation. This climatic characteristic is one of the most unstable climatic variables that affect the water resources of an area (*Rezaei* and *Abed,* 2010; *Mirzayi et al*., 2020). Since the temporal and spatial distribution of precipitation in Iran is affected by the distribution of global circulation systems, the slightest change in its pattern is followed by severe climatic anomalies. Therefore, spatial and temporal anomalies of precipitation, severe changes in precipitation intensity, and differences in the type of precipitation are the main features of precipitation in Iran (*Babaei* and *Farajzadeh*, 2002; *Mafakheri et al*., 2019). Local and regional climates are influenced by large-scale patterns of atmospheric circulation (*Kidson,* 2000). These patterns, along with fronts, cyclone and anticyclone systems, control different climatic elements and phenomena in mid-altitudes (*Zappa et al*., 2020). Iran's precipitation over time and in different places is affected by different patterns, systems, and climatic characteristics leading to a huge difference in Iran's annual precipitation in terms of time and place (*Farajzadeh et al*., 2002). In contrast to the Caspian coasts, Zagros and Alborz Mountains, which have very high precipitation, the central regions have much less precipitation (*Asgari* and *Rahimzadeh*, 2006). However, very low precipitation, in addition to heterogeneous spatial distribution, also has severe time fluctuations. Therefore, this heterogeneous temporal and spatial distribution in Iran is affected by the distribution of global circulation systems, and the slightest change in its pattern leads to severe climatic anomalies (*Frišmantas* and *Stankūnavičius,* 2020).

Due to its large size, Iran always benefits from different circulation systems, so that this situation has caused the mechanism of precipitation patterns in Iran to be different. For example, precipitation and the resulting processes in the southwest are mostly influenced by the strengthening and intensification of the Sudanese low pressure system and the Red Sea convergence region and their transformation into dynamic systems (*Lashkari*, 2005). This is why Sabziparvar considers the presence of deep troughs at a high level in addition to the above (so that the axis of the trough extends to the south to the south of the Red Sea) (*Sabziparvar,* 1991). However, circulation patterns in northwestern Iran are mostly influenced by the Siberian high pressure system, the mountain effects on atmospheric phenomena, the European high pressure systems, and the monsoon low pressure system (*Ashjaei*, 2000). On the other hand, the rains in the north of the countryare the result of the existence of a high pressure system, and the negative rotation dependent on the effect of the high pressure ridge located on the Caspian coast. It should be noted that in the high pressure and hybrid models, the most important mechanism of precipitation is the presence of cyclones in the region (*Mofidi et al.,* 2007), while some researchers have considered the occurrence of precipitation on the southern Caspian coast due to convection (*Alijani*, 2002). However, towards the lower latitudes, especially in the southeast part of the country, the mechanisms are more diverse and obvious. Limited studies have been performed on the synoptic pattern of autumn precipitation. For example, *Qian* and *Xu* (2020) examined the forecast of autumn precipitation in the Yangtze River Basin based on climatic indicators. The results showed that the spatial pattern of autumn precipitation changes is almost uniform throughout the region.

Any object that expands with increasing temperature decreases its density, and any object that contracts, increases its density. Therefore, with the fall of cold air, the density of air is compressed (increased), and consequently, the thickness of the atmosphere is reduced. Conversely, with the fall of hot air, the density of the air mass expands (decreases) and the molecules tend to diverge, which increases the thickness of the atmosphere following the divergence of the air molecules (*Rousta et al.*, 2016). Therefore, it can be said that every object that expands with increasing temperature decreases its density, and every object that contracts, increases its density. Since autumn is a transitional season between cold and hot seasons, the type of atmospheric thickness pattern is of great importance for the occurrence of precipitation in this season. As it has been observed, most of the analyses that have been done on autumn precipitation in Iran were done only regionally or as a transition of the effects, the changes of agricultural products, and its relationship with autumn precipitation (*Sohrabi et al*., 2020). Therefore, in this study, while examining and statistically analyzing the autumn precipitation in Iran, the atmospheric thickness pattern of the autumn precipitation has been studied and analyzed.

2. Data and methodology

The purpose of this study is a statistical-synoptic analysis of autumn precipitation in Iran with an emphasis on the atmospheric thickness. In this regard, two databases have been used.

1. Environmental data: This group of data (the so-called Al-Isfizari database) is obtained by the interpolation of stationary values of daily precipitation for the statistical period 1961 to 2003. This database has a spatial resolution of 15 × 15 km produced in the form of Lambert Conformal Conic Projection image system, and arranged in the form of a matrix of 15992 × 7187 with S arrangement (time in rows and space in columns). According to the time frame of this study (autumn season) with scripting in MATLAB software environment, data related to the autumn season (3848 days) has been extracted from the entire Al-Isfizari database and arranged in a matrix with dimensions of 3848 × 7187. In order to complete the 50-year statistical period and increase the accuracy of the research results, another set of relevant data from 2004 to 2010 using daily precipitation data of 1061 synoptic, climatic, and hydrometric stations, received from the World Meteorological Organization, was arranged and interpolated. The distribution of the stations used in both stages is shown in *Fig. 1 a* and *b*.

2. Atmospheric data: This part of the data that is used to calculate the thickness of the atmosphere includes geopotential height data in hPa unit, which is received from the database of the National Center for Environmental Prediction and the National Center for Atmospheric Research (NCEP / NCAR). The spatial resolution of this data is 2.5 × 2.5 degrees. One of the maps used in synoptic climatology is the thickness maps. These maps show the thickness of the atmosphere, which is usually between 500 and 1000 hPa. This thickness is considered as the thickness of the whole atmosphere. In fact, by examining the thickness between these two layers (thickness between the level of 500 and 1000 hPa), the condition of the whole layer is examined. According to *Rousta et al*. (2019), the thickness of the atmosphere has been calculated (*Fig. 1. c* and *d*).

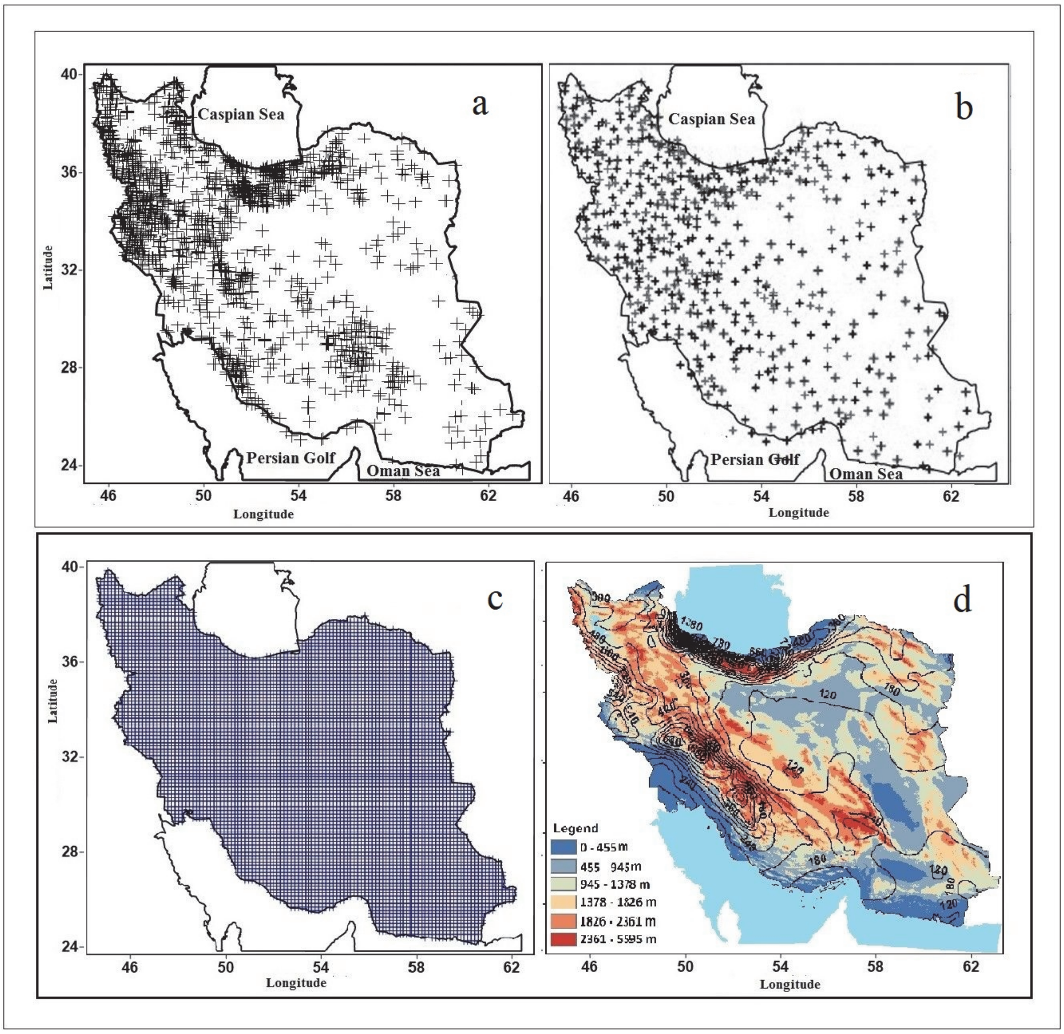

Fig. 1. Distribution of Al-Isfizari database (a), and distribution of supplementary stations (b), spatial resolution of NCEP/NCAR geopotential height data (c), and the calculated atmospheric thickness (d).

2.1. Methodology

In the present study, an attempt has been made to identify and analyze the thickness patterns effective in creating inclusive autumn precipitation in the country, using the environmental approach to the circulatory approach. After extracting the thickness of the atmosphere, cluster analysis was used to identify the thickness patterns of the inclusive autumn precipitation in Iran. In the next step, with the aim of classifying the atmospheric thickness data and identifying the representative days, a cluster analysis was performed on this data. The cluster analysis is a method in which variables are classified into specific groups based on the wanted characteristics. The purpose of cluster analysis is to find the actual categories of subjects and reduce the amount of data. In other words, the goal is to identify a smaller number of groups, so that data that are more similar to each other are grouped together in a way that the intragroup diffraction is minimal and the intergroup diffraction is maximal. In this method, data is grouped based on the distance or similarity between them. There are various methods for measuring the distance between data, one of the most widely used methods is the Euclidean distance method. In order to select the representative days of the groups obtained from the classification of data related to the atmospheric thickness, the Lund correlation method was used. In this way, to select the representative day, the day that has the most similarity with the maximum number of group of days is selected. The correlation coefficient represents the degree of similarity of the patterns of the two maps with each other. To do this, a certain threshold of the correlation coefficient must be accepted. The value of the correlation coefficient in such cases typically varies between 0.5 to 0.7 (*Yarnal*, 2011). Representative days were extracted based on a threshold of 0.5. Thus, the day that has a correlation coefficient of 0.5 with more days was selected as the representative day.

3. Results and discussion

3.1. Descriptive characteristics

Fig. 2 shows the spatial distribution of the monthly mean and the coefficient of the variation of autumn precipitation. The spatial distribution of average precipitation in October shows that the highest amount of average precipitation is related to the coastal shores of the Caspian Sea. The average precipitation in this part of the country reaches over 30 mm, while the southern and eastern parts of the country experience their minimum precipitation in October. Although the Iranian precipitation masses enter Iran from the west of the country in autumn, it is observed that due to local mechanisms, especially the huge source of Caspian Sea moisture, most of the precipitation is related to the Caspian shore (*Sari Sarraf et al.,* 2010). After the Caspian Sea coast, the Zagros Mountains, especially the Middle Zagros (western regions of the country) had the highest average precipitation in October.

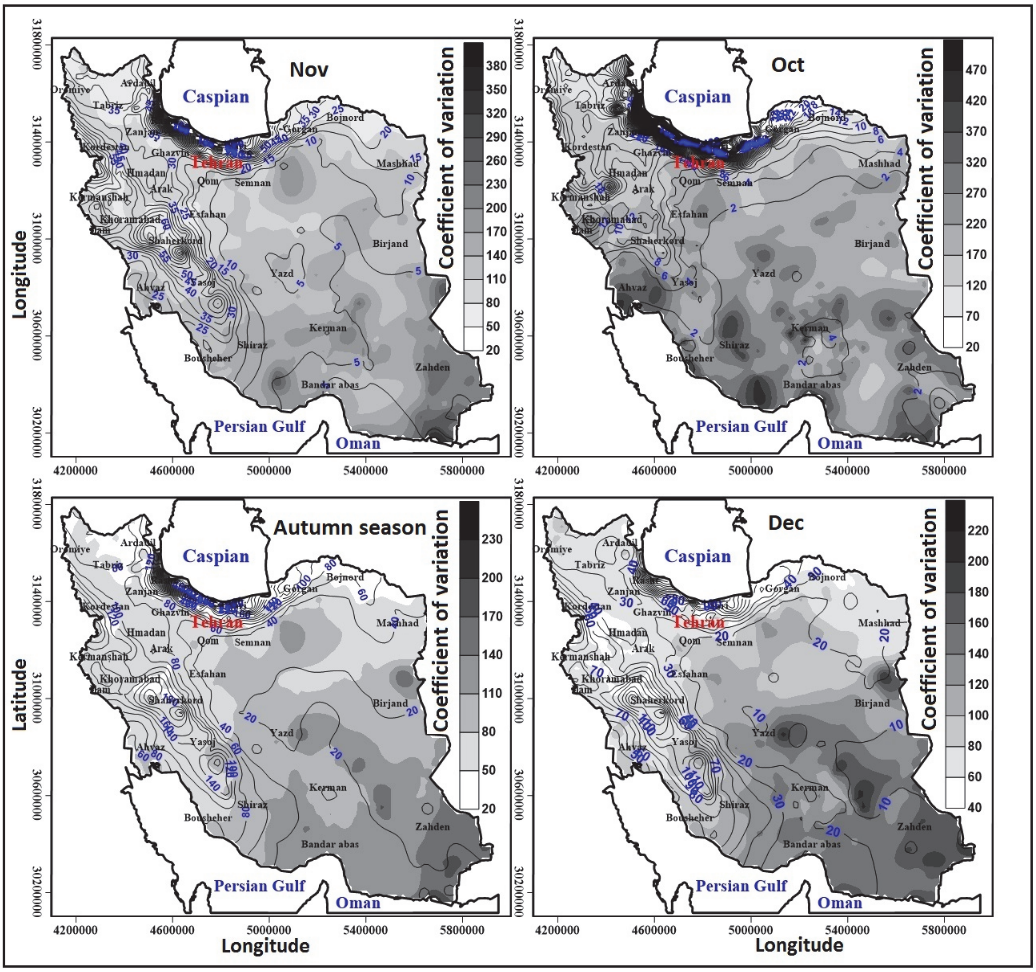

Fig. 2. Spatial distribution of the monthly mean and the coefficient of the variation of autumn precipitation in Iran.

Considering that autumn is a transient season between the departure of the subtropical high pressure from Iran and the beginning of the arrival of western winds in Iran, the spatial coefficient of variation of Iranian precipitation in autumn is extremely high, so that 90.8% of the country has experienced a coefficient of precipitation change above 100%. Therefore, the highest coefficient of variation in the form of more nuclei is scattered in the southern and eastern regions of the country. However, in this month, 91.8% of the area of Iran had less than 20 mm of precipitation (*Table 1*). In November, due to the fact that the western winds have entered Iran almost completely, the spatial distribution of precipitation throughout Iran has increased significantly. For example, the average precipitation compared to October in northwestern Iran has increased by about 15 mm and in the northeast by about 10 mm (see the November pattern of *Fig. 2*). However, in the southern half of the country, due to the fact that subtropical high-pressure systems have not yet completely left Iran, and on the other hand, western precipitation systems have less covered the southern regions of the country, the average precipitation in this month (November) has not increased significantly compared to October. However, the intensity of the spatial coefficient of variation of precipitation has decreased in this month, still many parts of the country have experienced a coefficient of variation is close to 100%. In this month, areas with precipitation between 20 and 40 mm reach 19.1%, while in October it was 5.2%. However, in this month, about 66% of the country has an average precipitation of less than 20 mm (*Table 1*).

Table 1. Mean classes and the coefficient of variation of autumn precipitation in Iran

		Average classification			
	class	**precent**		**class**	**precent**
	20<	91.8		20<	66.3
Oct	20 to 40	5.2	**Nov**	20 to 40	19.1
	40 to 60	1		40 to 60	9.3
	60>	1.9		60>	5.3
Dec	20<	42.8	**Autumn season**	20<	20.1
	20 to 40	31.8		20 to 40	35.6
		Classification			
	class	**precent**		**class**	**precent**
	40<	0		40<	0
Oct	40 to 70	4	**Nov**	40 to 70	6.2
	70 to 100	5.2		70 to 100	24.7
	100>	90.8		100>	69.1
Dec	40<	0	**Autumn season**	40<	3.5
	40 to 70	20.3		40 to 70	33.3

With the complete domination of western precipitation systems over Iran in December, the spatial distribution of Iran's average precipitation has increased significantly. In addition, with the stability of these precipitation systems in Iran, the spatial coefficient of variation of precipitation in Iran in December compared to October and November has decreased significantly. For example, in this month, 31.8% of the country has an average precipitation of between 20 and 40 mm, and 15.6% of the area of Iran, which covers most of the northern half of the country, has an average precipitation of more than 60 mm. The highest spatial coefficient of variation of precipitation of this month is observed in the southern half, especially in the southeast part of the country. As it was mentioned, the highest average precipitation in every three months is observed on the Caspian coast, because the local mechanism of the Caspian Sea plays an important role in precipitation in this region. The three types of Siberian systems, the high-pressure systems, low-pressure systems, and migratory cyclones are effective in precipitation on the southern shores of the Caspian Sea, among which, precipitation of Siberian high-pressure origin is more frequent. The required moisture of the precipitation caused by the Siberian high-pressure is due to the evaporation from the Caspian Sea. Whenever a short high-pressure ridge is established on the ground on the southern shore of the Caspian Sea, due to the spread of cold air in the region and there is a trough in the middle and upper levels of the atmosphere, the necessary conditions for heavy precipitation in the region are provided. It is necessary to explain that this cold air, when crossing the Caspian Sea, due to the season and the high sea water, becomes hot and humid from below, and as a result, it becomes unstable (*Moradi*, 2004). Therefore, the existence of the Caspian Sea as the main source of moisture, the presence of Alborz Mountains in the south of the coast and the dominance of north and northwest winds in the region cause the formation of suitable climatic conditions in terms of precipitation in this part of the country. With these conditions, generally, in autumn, the most precipitation has occurred along the Zagros Mountains and the coast of the Caspian Sea, which indicates the effect of altitude and distance to the sea in the spatial distribution of precipitation. For example, distance to the Caspian Sea and the altitude are the most important local factors influencing precipitation in the Talesh region (*Sari Sarraf et al.*, 2010).

In order to study and analyze Iran autumn precipitation in more detail, the monthly precipitation trend of autumn season is presented in *Fig. 3*, where the points seen on the map indicate the significance of the trend. The spatial distribution of the autumn precipitation trend indicates that in this season (except for October), in most parts of Iran, the precipitation has increased. In the distribution of precipitation in October in the northern half of the country, especially in the northwest, precipitation has decreased by an average of about -1 to -2 mm (*Fig. 3*). However, this declining trend was significant only on the Caspian coast at the 95% confidence level. In this month, although precipitation has increased in 40% of the area of Iran, it is observed that it has not been statistically significant (*Table 2*). In November the situation is almost the opposite, i.e., 40% of the area of Iran has a decreasing trend and the rest has an increasing trend (*Table 2*). In this month, the heights of Zagros in November has experienced a significant upward trend in contrast to October. In this month, despite the fact that precipitation has decreased in 40% of the country, less than 1% of it has been significant at the 95% confidence level (*Table 2*). In December, the trend of precipitation changes is completely different than that of October and November, so that in this month, precipitation has increased in almost 87% of the country. This increasing trend has occurred in the coastal shores of the Persian Gulf, along the Zagros Mountains and the southeast part of the country, especially the coastal areas of the Oman Sea (*Fig. 3*). Only 11% of these uptrends were significant at the 95% confidence level. In general, the distribution of autumn precipitation trend indicates that in most areas of Iran (above 80%), the autumn precipitation has been increasing. This upward trend along the Zagros Mountains reaches over 5 mm. However, significant trends are scattered throughout Iran. Still, the western parts of the Caspian Sea coast have experienced a downward trend of about -3.5 mm.

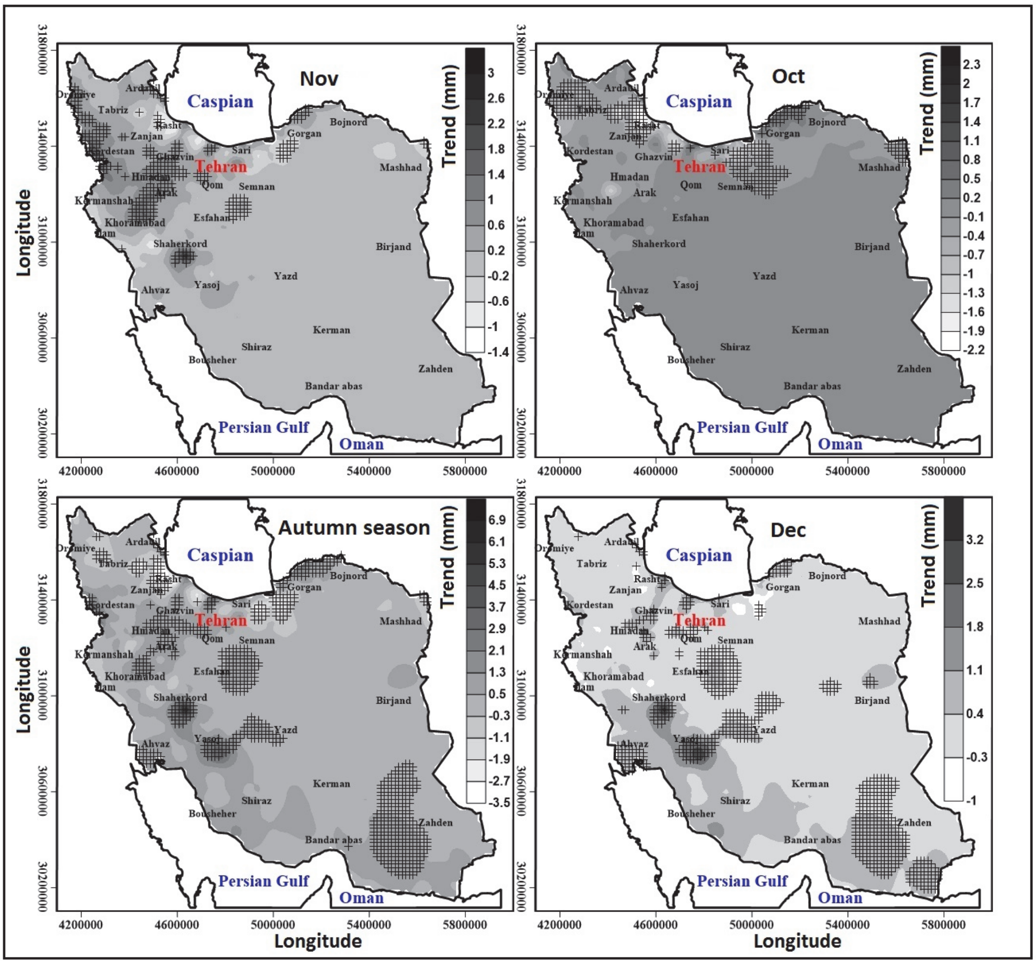

Fig. 3. Spatial distribution of the monthly trend of autumn precipitation in Iran.

Table 2. Type and percentage covered by the trend of autumn precipitation in Iran

Month	trend type	Percentage covered	The significance level	Percentage covered	Month	trend type	Percentage covered	The significance level	Percentage covered
Oct	decreasing	59.2	sig	4.9	Nov	decreasing	41	sig	0.47
			non sig	54.2				non sig	40.5
	increasing	40.7	sig	0.58		increasing	58.9	sig	4.4
			non sig	40.1				non sig	54.2
Dec	decreasing	12.8	sig	0.11	Autumn season	decreasing	19.9	sig	1.8
			non sig	12.7				non sig	18.1
	increasing	87.1	sig	11.5		increasing	80.1	sig	11.1
			non sig	75.5				non sig	68.9

3.2. Synoptic analysis of the autumn precipitation thickness

Fig. 4 shows the dendrogram of the cluster analysis on the atmosphere thickness of the Iranian autumn precipitation. According to *Fig. 4*, atmospheric thickness maps were drawn for the representative days of different groups (2 to 7 groups) at the correlation level of 0.5, then, by comparing the maps of the representative days of the members of each group and through the trial and error method, the appropriate place to cut the chart and the appropriate grouping number to extract the patterns were determined. According to the studies, the division into four groups was found appropriate, and the representative days of each group have been determined. According to *Fig. 5*, the highest frequency of the autumn precipitation patterns is the fourth pattern.

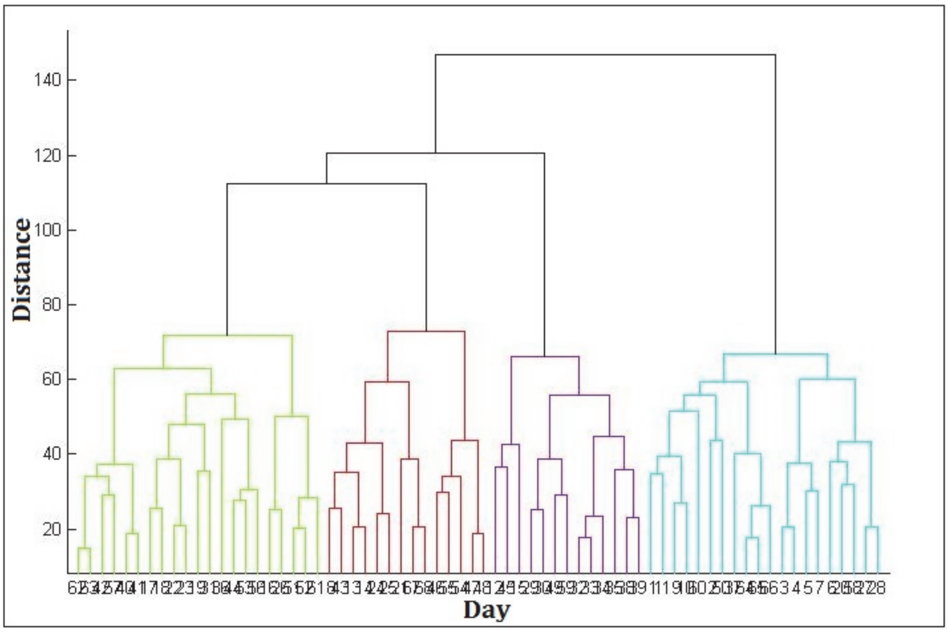

Fig. 4. Dendrogram from cluster analysis on the atmospheric thickness of inclusive autumn precipitation.

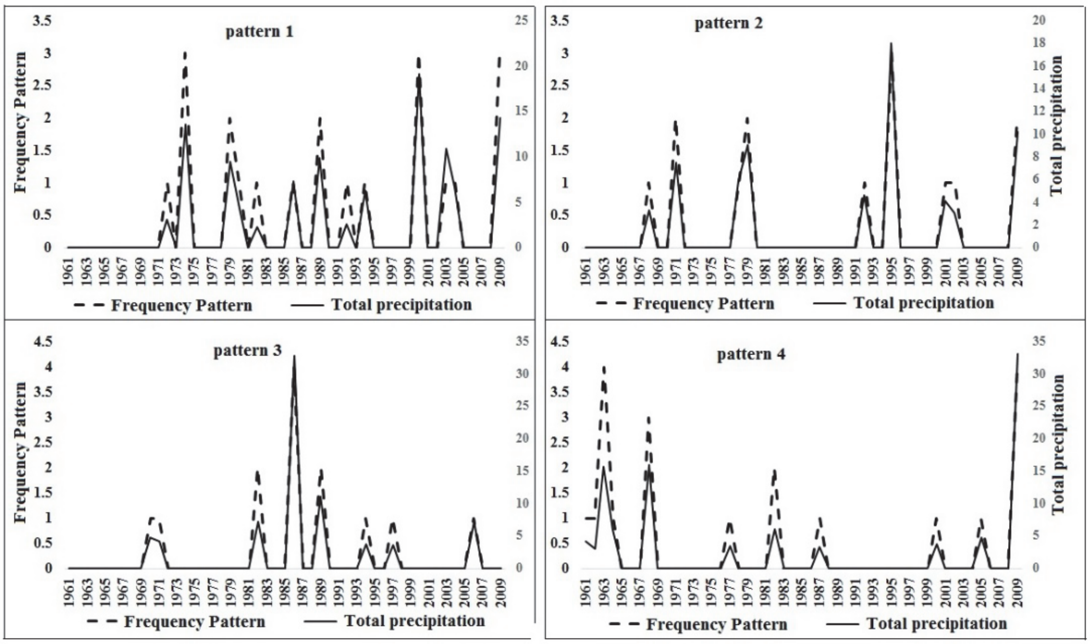

Fig. 5. Frequency and total autumn precipitation for different patterns during the study period.

Fig. 6 shows the patterns of atmospheric thickness of autumn precipitation in Iran. *Fig. 6a* shows that a deep ridge extends from the western part of the Mediterranean to North Africa and over Algeria. Although this ridge has a great depth, its wavelength is not very wide and has not affected a large range (*Fig. 6a*). Since the western part of the ridge is accompanied by a negative vorticity (*Lashkari*, 2005), it has caused the cold and humid air to advect from the Mediterranean Sea to the northern regions of the Middle East, but in the central regions of the Middle East, it has caused ridges and has led to the advection of hot air (*Fig. 6a*). On the other hand, a low-altitude system with a cold core is located in the central regions of Iran, so that the minimum thickness of the atmospheric layer in the Middle East region fully corresponds to this low-altitude system, and its descending arm has caused the transfer of cold air from higher latitudes to lower latitudes, affecting Iraq, Saudi Arabia, southwestern Iran, and the Persian Gulf basin. Given this, it can be said that the cold air flow that has descended from the western half of ridge on Iraq, the western parts of Iran, the northern parts of Saudi Arabia, and the Persian Gulf basin, in response to the warm weather that has spread from Northeast Africa and Saudi Arabia, has created an allobaric zone on the study area, and has provided conditions for atmospheric instability (*Rezaei Banafsheh et al*., 2015). Since the thickness of the atmosphere is different due to the type of prevailing air (*Fig. 6a*), the highest thickness of the atmosphere is in the southern regions of the Middle East, especially in the southern parts of Saudi Arabia, the Arab Sea, and the Persian Gulf, because in autumn the high latitude atmospheric systems are not strong enough to advance to the low latitudes of the study area, and the lowest thickness of the atmosphere is located in the central regions of Iran, which is completely consistent with the dynamic low-altitude system (*Masoudian*, 2005). The spatiotemporal distribution of the autumn precipitation pattern of the thick layer of the Middle East atmosphere indicates that a wide low-altitude system with average pressure (5390 geopotential meters) was formed in Northern Europe and crossed the Black Sea into the northern parts of the Middle East (*Fig. 6b*). This low-altitude system has transferred cold air from high latitudes to lower latitudes, and since it has crossed the Black Sea and the eastern parts of the Mediterranean, it has transferred moisture to the northern regions of the study area. During the rule of this model, the flows drawn on the central and southern regions of the Middle East, due to the low latitude, have transferred cold air to the study area, and this has caused high pressure gradients and instability in the northern regions of the Middle East. However, due to the fact that the low altitude system of Northern Europe extends over the Black Sea and the Mediterranean, it can bring a lot of moisture to the study area (*Fig.6b*). At the same time, the warm air mass has penetrated from North Africa to the central and southern regions of the Middle East, so that the southern regions of the Middle East have the highest thickness of the atmosphere (5650 to 5750 meters) and the northern regions have less atmospheric thickness. The spatiotemporal distribution of the third pattern (*Fig. 6c*) of autumn precipitation for the thick layer of the atmosphere in the Middle East shows that two low-altitude cores are located in the Mediterranean Sea and southwestern Europe, directing eastward flows to North Africa. On the other hand, a deep ridge is located in the northern regions of the Middle East, and in the western part of the ridge, cold air has fallen in the northern regions of Europe towards the northern regions of the Middle East, in such a way that in the central regions of Turkey it has led to the phenomenon of blocking and a wide range of cold air advection into the Middle East. On the other hand, since the central regions of the Middle East are under the influence of the hot weather of North Africa, there is a high pressure gradient in the northern and central regions of the Middle East, as it is clear from the compaction of the same height lines (*Fig. 6c*).

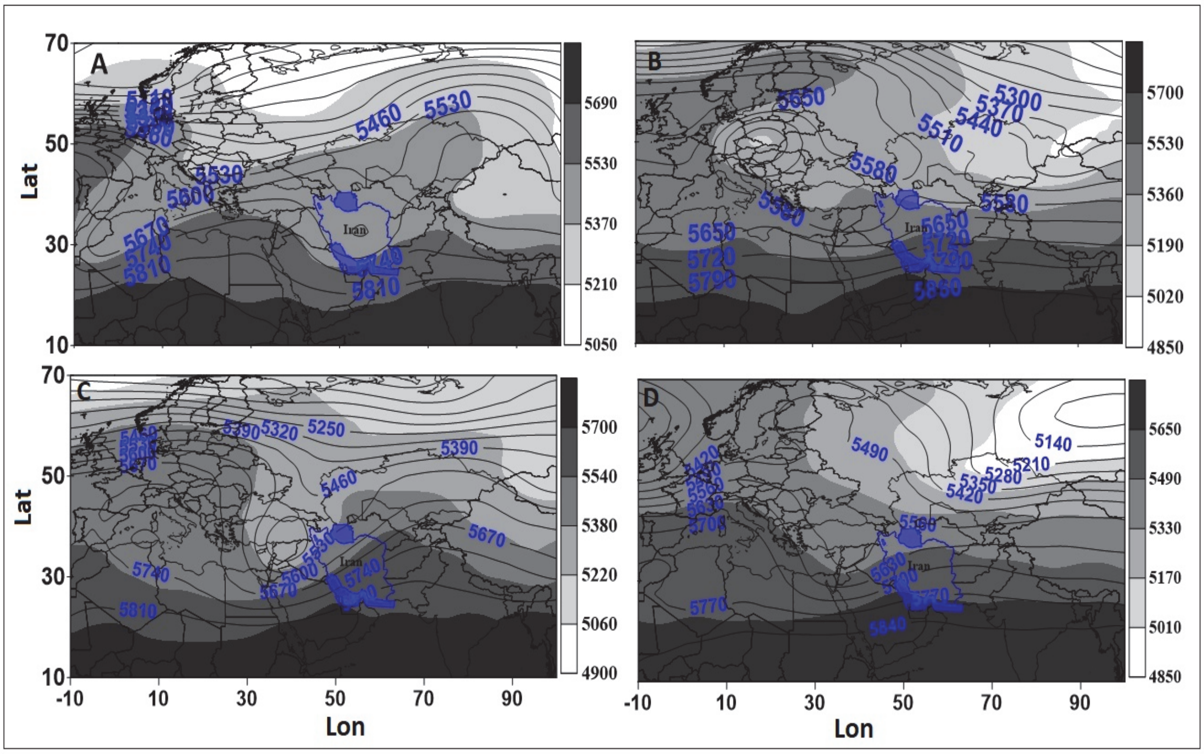

Fig. 6. Patterns of atmospheric thickness and height of atmospheric geopotential for autumn precipitation in Iran.

It is also observed that the passage of cold flows of high latitudes through the northern regions of the Middle East has caused compaction of the thick layer of the atmosphere and reduced the thickness of the atmosphere. So that the minimum amount of atmosphere thickness (5000 meters) is completely consistent with the blocking located in Turkey and the maximum amount of atmosphere thickness (5700 meters) is in the southern regions of Saudi Arabia, because it is completely under the influence of the hot weather of North Africa. The large difference in atmospheric thickness in the southern and northern regions of the Middle East region indicates the large temperature difference in the thick layer of the atmosphere (*Fig. 6c*). During the reign of this model, the cold air of Europe falls through this deep trough and the penetration of hot and humid tropical air from the Red Sea, which is characterized by the establishment of ridges in the eastern and northeastern pats of Iran. Baroclinic conditions are established in the Middle East and cause widespread precipitation in the northeastern regions, especially in the western regions of Iran (*Masoudian* and *Karsaz,* 2013). The spatiotemporal distribution of the fourth autumn precipitation pattern shows that the establishment of the trough on Europe and its eastern part location in the Eastern Europe has caused cold air to fall to the lower latitudes and the northern regions of the Middle East. As a result, the thickness of the atmosphere in the northern regions of the Middle East has reached a minimum (5350 meters) in the northern regions of the Middle East (*Fig. 6d*). At the same time, a weak low-altitude system with a cold core has been deployed in North Africa, preventing cold and humid Mediterranean air from flowing into North Africa in its cyclonic motion. On the other hand, the orbital flows of North Africa and their passage through the southern regions of the Middle East indicate the advection of hot air in the study area, which together with the cold European air fall by deep European trough leads to a baroclinic atmosphere, fronts and finally instability in the northern regions of the Middle East. However, the peak of baroclinic instability is in the northern regions of Saudi Arabia, Iraq, and western Iran, which, due to the transport of moisture from the Mediterranean, the Black Sea, and the Red Sea, can cause widespread precipitation in the study area (*Fig. 6d*).

4. Results

The results of the analysis of the autumn precipitation trend indicate that although the precipitation has increased in most areas, except for limited areas including the Zagros Mountains, other areas have not experienced a significant upward trend. Also, a decreasing trend has been observed in the form of spots along the coastline in the Caspian Sea. The results of the analysis of the thickness pattern of autumn precipitation showed that since low-altitude systems, troughs, and air fronts provide conditions for atmospheric instability, the establishment of low-altitude systems on Iran and the transfer of cold air and moisture from the Mediterranean Sea by the Mediterranean trough to the western regions of the Middle East have caused precipitation in the region. Therefore, the expansion of the European low-altitude system and its crossing over the Mediterranean and Black Seas, along with the transfer of Red Sea moisture to the central regions of the Middle East and the creation of an allobaric atmosphere in the northern regions of the study area, have provided instability and precipitation in the Middle East. Also, the passage of northern flows over the Black Sea and induction of blocking phenomenon in the central regions of Turkey have caused severe instability and possibly widespread precipitation, but the location of the eastern part of the trough on Iran, which is accompanied by positive vorticity, maximum ascent, and instability can cause widespread precipitation by transferring moisture from the Black Sea, the Persian Gulf and the Red Sea. According to the precipitation patterns of autumn, it can be said that the rains in the Middle East region occur due to baroclinic instability due to cold and humid air of high altitudes and hot and humid air of low latitudes in North Africa, in such a way that the Black Sea and the Mediterranean Sea provide the required moisture in the high latitudes and the Red Sea and the Persian Gulf provide the required moisture in the low latitudes. The thickness of the atmosphere in the Middle East in autumn has the most fluctuations and changes, because the temperature difference in autumn in the Middle East is very large due to the infiltration of westerly winds to the north and the prevailing warm weather in the southern regions of the Middle East.

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