Analysis of behavior pattern and thermodynamic structure of Arabian Anticyclone in early onset of precipitation in south and southwest of Iran

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Research Article

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Abstract

In Iran, due to its geographical location to the general circulation of the atmosphere and atmospheric systems adjacent to the time distribution of precipitation is not uniform. In the southern part, the main focus of the precipitation period is in autumn and winter, and by moving to the middle and northern latitudes, the precipitation period gradually lengthens and covers the autumn to spring seasons. According to the country's agricultural calendar, precipitation l is expected to start in early or mid-October. But in practice, due to the planetary and regional circulation characteristics, it sometimes happens sooner or later than normal conditions The purpose of this study is to identify synoptic patterns as well as the role of Arabian Anticyclone (AA) in the early onset of precipitation in south and southwestern Iran. For this purpose, daily precipitation of synoptic stations in the south and southwest of Iran in a statistical period of 36 years was extracted and based on the criteria set, early precipitation years were determined. Dominant synoptic patterns in these years were extracted using factor analysis and ocular inspection methods. In the following, the vertical structure and spatial displacement of the Arabian anticyclone have been investigated. The results of this study showed that in both patterns, Arabian anticyclone has been removed from its summer pattern earlier than normal conditions and according to the pressure level, it has been established in the area between the Hormoz Strait and the Aden Gulf. In both patterns, about 7 to 10 days before the onset of rainfall, a deep ridge of African anticyclone with the expansion of Northern (blocked in a pattern on northern Europe) intensifies the northern flows over the eastern Mediterranean and north-east Africa. This pattern with cold advection; in addition to deepening the Mediterranean trough and intensifying the activity of the Sudanese system is by the eastward displacement of the Arabian anticyclone. The vertical and horizontal profiles showed the eastward displacement of the Arabian anticyclone cores at least 15 days before the early precipitation.

1 Introduction

Subtropical high pressure is one of the main elements in the bone of general circulation of barley. Due to its geographical location and its location in the tropical latitudes adjacent to the subtropical high-pressure belt, Iran is one of the main elements of the general circulation of the atmosphere. This geographical location has caused most of Iran to be directly affected by this strong dynamic high-pressure system. Having an arid and semi-arid climate in a large part of the country is the result of this proximity. This proximity has also caused the precipitation distribution in Iran to be limited to a small part of the year and during the domination period of this high pressure on Iran, precipitation is interrupted or very low, and the main controller of this precipitation period is the spatial displacement of subtropical high-pressure cells and the nearest and most effective high-pressure cell on Iran is the Arabia high pressure cell. The south and southwestern parts of Iran have the closest position to this high-pressure cell. Therefore, it accepts the greatest impact throughout the year from this climatic system. As a result, the spatial displacement (long and transverse) of this high-pressure cell, whether independently or in combination, is extremely effective in the beginning and end of precipitation in this region, note that south and southwest of Iran have a warmer climate due to being located at lower latitudes and is one of the few parts of the country where the cultivation period and rainfall period are disrupted. Therefore, displacement at the early precipitation in this region can have significant effects on yield, quality and efficiency of agricultural products. This part of Iran is the most important part of the country in terms of supplying fruits and vegetables during the winter period of Iran and neighboring countries. This proximity has also caused the distribution of precipitation in Iran to be limited to a small part of the year and during the period of domination of this high pressure on Iran, precipitation is interrupted or very low and the main controller of this precipitation period is the displacement of subtropical high-pressure cells and the closest and most effective cell. High-pressure on Iran is the Arabia high-pressure cell. The southern and southwestern part of Iran is closest to this high-pressure cell. Therefore, it receives the most impact from this climatic system during the year. As a result, the spatial displacement (longitudinal and transverse) of this high-pressure cell, both independently and in combination, is very effective in the beginning and end of precipitation in this region. Note that the south and southwest of Iran have warmer climates due to their lower locations. It is one of the few parts of the country where the cultivation period and the rainfall period coincide. Therefore, displacement at the early precipitation in this region can have significant effects on yield, quality and yield of agricultural products. This part of Iran is the most important part of the country in terms of winter fruits and vegetables supply to Iran and neighboring countries. The classification and acquisition of circulatory patterns has increasingly entered the atmospheric sciences with the advancement of computer science. In some studies, cluster analysis and key component analysis in Spss and Matlab software have been used to identify the prevailing atmospheric patterns (Kaviani et al. 2007; Afshar Manesh 2010; Fowel et al. 1993; Domers et al. 1998, Kerry et al. 1999, Al-Hamrahndan 2002, Turkish 2009, Lopez 2008) In some studies, two patterns (Kaviani et al. 2007) and in others four patterns have been identified as precipitation-generating patterns (Bart and Stonkel 2004, Afsharmanesh 2010). In different countries, a lot of research has been done on the relationship between the early, end and duration of annual rainfall, most of which is related to Africa, Australia and Brazil. In addition to research on atmospheric patterns and how they affect the beginning of early precipitation, the relationship between the onset time of precipitation and the total rainfall received during the period has also been significant. Hotfield (1990) calculated the onset date of rainfall with three indicators for arid and semi-arid regions; In the first index, the start date of rainfall is the first day that the total precipitation reaches 15 mm from the beginning of autumn, in the second index, it is the first day of the first autumn that the total precipitation is 5 mm, provided that 15 days after that date is not a dry day. In the third index of the early precipitation, it is the first day since the beginning of autumn when the total rainfall reaches 20 mm. Connery (1933) For example, early autumn precipitation in the United States is more homogeneous and uniform than late precipitation. But the research of Pharmacists (1980) and Joseph et al. (1994) do not show a relationship between the onset time and intensity of monsoon rains. They also made it clear that Amazon's seasonal rainfall anomalies would not make a significant correlation between when rainfall started and how much it rained. Kotil (1988) in his research has shown that the early precipitation (rainy season) in occupied Palestine with the longitude of stations, the length of the rainy season with the height of stations and the end of rainfall have used different indicators. Diane et al. (2001) described the early occurrence of precipitation before the beginning of the cold season in the eastern Mediterranean as a result of the southward displacement of the tropical river from 29 ° north latitudes. Hashigonta et al. (2007) in a study analyzed the start date and length of the rainy season in Zambia and their results showed that the rotational anomaly of the seasons in the early beginnings in northern Zambia is not normal and is different from North Africa and South Africa. In a study, Lax et al. (2008) predicted the early rainy season in West Africa, and the results showed that the use of current precipitation and linear regression models to estimate the early rainy season is a good way to study the early rainy season. Lema et al. (2009) in a hierarchical modeling study on the return period of daily precipitation of early onset, peak, and cessation of precipitation and the results showed that a negative anomaly in the tropical South Atlantic with sea level temperature between January and March can Early onset of precipitation affects the northern, eastern and northeastern coasts of Brazil. Lema et al. (2009) in a hierarchical modeling study on the return period of daily precipitation of early onset, peak, and cessation of precipitation and the results showed that a negative anomaly in the tropical South Atlantic with sea level temperature between January and March can Early onset of precipitation affects the northern, eastern and northeastern coasts of Brazil. Kamblin et al. (2009) considered three variables for rainfall, which include the amount of total rainfall, the number of rainy days and the intensity of daily rainfall. The results showed that in long seasons, the total seasonal precipitation does not have a suitable pattern and makes it difficult to predict. In short rainfall, on the contrary, although they have more onset and more continuity than the end, the rainfall is stronger and more continuous seasonally. Wang et al. (2009) A 60-year study of rainfall and 850 hPa currents in the southern Arabian Sea has been used as a numerical model in simulating and predicting changes in summer rainfall in the region. Francesco et al. (2010) examined the onset and end of rainfall in Brazil's Sao Paulo for corn production, and the results showed that in the period 1970-2003, rainfall and rainfall season occurred at a time when El Nino was strong in the region, while in Lanina incidents, rainfall seasons were lower and rainfall decreased. Research on changes in the early and end of inclusive precipitation in Iran is also more important in terms of the location of the country in different latitudes, the establishment of subtropical high pressures and the lack of conditions for climbing and precipitation in most of the year. The propagation of the western waves and the movement of the polar equator towards the lower latitudes, simultaneously with the retreat of the subtropical high pressures, determine the time of the beginning of the total rainfall in the country (Alijani 1995: 41). Hejazizadeh, (1993) in a long-term forecast of the early precipitation in the cold period of the year has studied the pattern of 500 and 1000 hPa levels and while examining the movement of the polar peak and its relationship with subtropical high-pressure, the associated values of precipitation are related to the aforementioned factors. Kamali (1997) has also considered 5 mm of rainfall as an indicator to determine the date of early precipitation in rainfed areas in the west of the country. Nouhi (2000) considers the best indicator to be the first day of the first of October when the total precipitation reaches 10 mm in one or two days. Yazdani (2014) in the study and analysis of synoptic patterns and patterns of atmospheric circulation in the years with early onset of precipitation at the level of 500 and 1000 hPa and finally with Tukey test had a significant correlation at the level of 5% between early onset of cold precipitation in each year Area and total rainfall received for that period. Among the recent works are (Karimi et al., 2019; Alipour et al,2019; Mohammadi and Lashkari,2019; Khoshakhlagh et al.,2020; Lashkari et al,2021). In general, less synoptic work has been done in the field of start and end as well as the duration of rainfall period in external and internal sources, and most of the research has been on the effect of start and end on crop yields. The aim of this study is to investigate the vertical profile in Arabia subtropical high-pressure and its role in early precipitation in southern and southwestern Iran.

2 Methodology

Although, according to ancient beliefs and the patterns of atmospheric circulation in the Middle East and West Asia, the rainfall of the crop year in Iran should start from October. However, autumn rains do not start the same in all parts of the country and every year. Studies show that the Arabian anticyclone has a controlling role in the atmospheric circulation of the Middle East region. Therefore, the hypothesis was strengthened that the early onset of precipitation in some years was related to the spatial displacement of this anticyclone. With this assumption, the role of this system in synoptic patterns leading to early onset and its dynamic structure was considered in this study. For this purpose, in the first step, the daily precipitation data of synoptic stations in the south and southwest of Iran) Kohkilouyeh and Boyerahmad, Chaharmahal Bakhtiari, Lorestan and Ilam) were received from the Meteorological Organization in a 36-year statistical period (1979-2015). All stations that had complete and flawless data during this statistical period were retained and the remaining stations were discarded.

In the second step, three criteria were defined to determine the day of start precipitation;

At least 50% of the selected stations in the study area were involved in precipitation.

More than 5 mm of precipitation has been recorded in at least one of the selected stations.

Rainfall lasts more than a day.

Thus, the early precipitation was selected when a precipitation system entered the region and local and scattered precipitation was not considered as the start day. Based on the above criteria, 36 days of onset were selected.

In the third step, and considering that the beginning of autumn in Iran is set as the start irrigation year. September 22 was chosen as the starting point for counting the rainy start day. Thus, the interval between the days of precipitation and September 22 it was counted. For example, if the first day of the early precipitation was October 15 of the year, the distance from the day of onset 15 + 9 = 24 days was calculated. This activity was performed for 36 years and 36 numbers were obtained as the distance from the beginning.

In the fourth step, the numbers were arranged from the beginning and their 90th percentile was determined. Figure 1 shows the years with early onset. Approximately 20 days from the September 22 in the 90th percentile or early start in the south and southwest of Iran is considered.

Due to the fact that the rainy season in the south and southwest of Iran is in the range of early October to late May. According to the purpose of the study, which was to identify patterns leading to early precipitation. To investigate the synoptic conditions before the early precipitation. Atmospheric data for

30 days before the early precipitation years at the sea levels, 1000, 925, 850 and 700 hPa, was retrieved from the National Oceanic and Atmospheric Administration. For example, if the precipitation had happened on October 10th. Atmospheric data were collected and stored from October 10 to 30 days earlier (September 20th). This data was collected for all 11 years with early precipitation.

Fig.1.

Due to the fact that the prevailing synoptic conditions had to be checked 30 days before the start precipitation. For each atmospheric level (492 days), scripts were written in the GRADS software environment in the early stages, and .txt data was extracted. Then; for each level matrix with 2145 * 249 was extracted in the range of -60º to 100º E longitude and 0º to 80º N latitude for 11 years with early start precipitation. Then, in Unistat 10 software environment, the necessary calculations were performed by factor analysis of the base component and the waxing period (varimax) and the dominant patterns were extracted. In order to increase the accuracy in selecting the prevailing and repetitive synoptic patterns, all these maps were drawn at four sea levels, 1000, 925 and 850 hPa, and were visually reviewed several times. By adapting the prevailing and repetitive patterns obtained from factor analysis and visually analysis, the years 1982-1983 and 2000-2001 were selected and analyzed as the prevailing synoptic patterns in early start precipitation years. These two years better than other years showed the prevailing synoptic pattern in 11 years with early start precipitation.

For analyze the role of spatial displacement of Arabian anticyclone in early start precipitation, a vertical and vertical profile IS drawn at levels of 700 and 850 hPa at 20 to 60 ° E longitude and 20 ° N latitude for all days before precipitation (30 days for 11 years).Considering the role of east and southward displacement of Arabian anticyclone in providing suitable conditions for the entry of southern precipitation systems and at the same time moisture advection into the input systems, the longitude of 60º E has been selected. This longitude corresponds to the geographical area east of the Hormuz Strait and east of the Arabian Peninsula. If the Arabia high pressure is located in this geographical area, the conditions for the entry of precipitation systems will be possible (Mohammadi et al,2021; lashkari and Mohammadi,2015).

2.1 Study area

For this research, the southern and southwestern regions of Iran (Includes provinces: Khuzestan, Bushehr, Hormozgan, Fars, Kohkiluyeh and Boyer-Ahmad, Chaharmahal and Bakhtiari, Lorestan and Ilam) have been selected. In this regard, the study of changes in the length of the rainy season is very important in terms of impact on the production of agricultural products in the cold period of Iran. On the other hand, this region is in the neighborhood of three important systems (Sudan low, Arabian anticyclone and subtropical jet stream), which have a great impact on the climate of the West Asian region. Thus, understanding their behavior and the synoptic pattern is very important for the countries of this region. Figure 2 and Table 1 present the location of the study area and the characteristics of the selected synoptic stations.

Figure 2.

Table 1.

3 Results And Discussion

Early precipitation in the south and southwest of Iran, which is part of the tropical region, is very important. Due to the possibility of autumn cultivation in this region of the country, the autumn rainfall and its early start is very important in terms of agriculture. The aim of this study was to identify the synoptic patterns before the early precipitation in the years when the precipitation started earlier than normal. In the years when the precipitation started earlier than normal, there were two general patterns. In the following, these two patterns are analyzed

3.1 Sudan-Pakistan low pressure integration pattern and eastward movement Arabian anticyclone (PC1)

As can be seen in the lower layer of the troposphere, especially the 1000 and 925 hPa levels, three atmospheric systems control the Middle East and Southwest Asia region. Due to the seasonal situation and thermal characteristics of the region, Pakistan low pressure still dominates the eastern and southeastern half of Iran. The trough of this low pressure has covered much of Iran. These conditions, especially up to the level of 925 hPa, are the dominant phenomenon in Iran. Another influential system in the atmospheric circulation of the region is the African anticyclone system.

This system; that his central core is located in Northwest Africa. In eastward Expanding, it covers the entire width of African sub-Saharan and extends from the northern to the southern half of Europe and the northern Mediterranean. This system is one of the effective systems in activating the Sudanese system with anticyclonic circulation and cold advection of the northern latitudes. Cold advection from the southward currents of the eastern trough of African anticyclone has created a strong pressure and geopotential gradient behind the Sudanese system.

As can be seen, the Sudanese system is expanding to the northern latitudes in perfect conditions. Arabian anticyclone due to its thermodynamic structure (thermal characteristics of the Arabian Peninsula) in the lower levels has not appeared as an independent system. Rather, it has appeared as a anticyclone ridge along the ridge of African anticyclone on the Arabian Peninsula.This ridge by anticyclonic circulation has played an important role in providing suitable thermodynamic conditions for the early development and strengthening of this system by moisture advection from the warm Arabian and Omani seas entering the Sudanese system. Moisture core on Sudan and the Red Sea are a good indication of this moisture advection.

. As a result of this moisture flux, the special moisture in the core of Sudan low reaches more than 12 to 16 g / kg (Figures 3A and 3B). As can be seen on the 850 hPa level chart, the Arabian anticyclone has been formed as an independent cell in the east and southeast of the Arabian Peninsula. Although this cell is located along the African anticyclone ridge. But it is in very good condition for moisture advection into the Sudanese system. Moisture zone with a special moisture of 8 to 12 g /kg is the result of this moisture flux by Arabian anticyclone. But Sudan's low trough is still in its normal position. Due to its thermal nature, the Pakistani thermal low is not observed at this level (Figure 4 A).

Sudan and Pakistan thermal lows systems are not seen at 700 and 500 levels (Figure 4B and Figure 5), which are close to the middle layer of the troposphere. Arabian anticyclone has turned into a completely independent system due to its dynamic structure in the middle levels. The eastward movement of this anticyclone has provided very favorable conditions for the penetration and expansion of the southern Mediterranean trough towards the Red Sea. The southern end of trough extends to the north of Sudan (latitude 15º). In other words, this eastward shift, which normally occurs in late November. (Mohammadi et al., 2018) In the years with early start precipitation, this southward and eastward shift has occurred much earlier than normal. And good circumstances for the early displacement of westerly waves to the southern latitudes have been provided. With the domination of the northern currents, in addition to cold advection and, Positive vorticity injection on the region, conditions have been provided for the strengthening of the Sudanese system.

Figure 3.

Figure 4.

Figure 5.

3.2 Sudan-Mediterranean integration pattern and southward movement of Arabia anticyclone(PC2)

These synoptic patterns justify three years (1983-1982, 1992-1991 and 2001-2000) of the early start rainfall y ears, in this pattern, a combination of the performance of four systems, the Sudanese low pressure, the Mediterranean cyclone, the Arabian anticyclone, and the blocked migratory anticyclone, play a major role in the early start of precipitation in southern and southwestern Iran. In this pattern, from 6 to 8 days before the early start precipitation, a ridge of African anticyclone with deep northward expansion (up to 70º to 75º N latitude) has blocked the usual arrangement of westerlys. From the second or third day, with the closing of the first contour under the ridge, it becomes a block. Due to stopping or slow movement of blocked anticyclone, the north flow gradually intensify on the eastern slopes of the block and with cold advection from the northern latitudes a deep trough form on its eastern side. Deepened trough with cold advection and vorticity injection on the region have led to the early development and strengthening of the Mediterranean and Sudanese systems. As can be seen in this pattern, Saudi Arabia anticyclon has displacement south and eastward considerably. In this pattern, unlike the before pattern; Arabian anticyclone from the level of 1000 hPa, it is located as an independent cell on the eastern coasts of Oman and eastern Arabian Peninsula. The pattern of deployment of Arabia anticyclone cell is such that it is available in all levels, especially the lower layer of troposphere, for moisture advection from the Arabian and Oman seas in the system. The combined chart of the special humidity in the underlying layer of troposphere shows this phenomenon well. As a result, the wet cell with a special humidity of 18 to 22 g/kg is a large part of Sudan and the Red Sea .

Figure 6.

Figure 7.

Figure 8.

As seen on chart of 850 hPa levels and above. With the intensification of omega blocking on Central Europe, it has spread to above 70º N latitude. By northward expansion the ridge, the flows on the east side of the block are completely meridional. With the cold advection of the polar latitudes on the eastern Mediterranean and western Asia and the positive vorticity advection of it; the trough in the eastern Mediterranean has been completely strengthened. With the expansion to the southward of trough and cold advection on the region, suitable conditions have been provided for the formation of the Mediterranean cyclone and the trough of Red Sea and Sudan. In contrast, Arabian subtropical anticyclone is located on the west coast of the Oman and Arabian Sea with a very convenient east and southward shift. This pattern of establishment has created very suitable conditions for moisture advection into Sudan low in the lower levels of troposphere. Also, by moving south and eastward moving of Arabian anticyclone, the good bases has been provided for the expansion to the south of the Mediterranean trough. With the expansion to the southward of the Mediterranean trough, both precipitation systems (Mediterranean cyclone and Sudan low pressure) have been activated earlier than usual and have provided early autumn precipitation in Iran.

3.3 Horizontal profile pattern (longitudinal and transverse) of Arabian anticyclone before the startof precipitation in the years with early autumn precipitation

In this part of the research, to identify the spatial displacement of Arabian anticyclone from 15 days before the early precipitation, the latitudinal and longitudinal profiles have been extracted at the levels of 850, 700 and 500 hPa. For the sake of brevity, only the 700 and 500 hPa level diagrams are provided. Figures 9 and 10 show the geopotential height profiles of the 700 and 500 hPa levels for the two dominant patterns described above. In this section, the 50 ° east longitude as a fixed axis and the width range from zero to 70 ° North is selected as the variable axis. Each of the curves shows the geopotential height position of the one day before the start of precipitation. Figures 9A and 10A show the position of the geopotential height of 500 hPa. As can be seen, at the level of 500 hPa, the geopotential height curves start in the range of 5820 to 5880 geopotential meters and in the range of 25º to 30º N, which corresponds to Oman and the Hormuz Strait, The height of the curves increases by about 30 to 40 geopotential meters and then decreases rapidly from 35 °n. This phenomenon indicates the existence of a high-altitude field in the range between the equator to a latitude of 30 º N. This high-altitude field is the Arabia anticyclone in the eastern position of the Arabian Peninsula. The northern edge of this anticyclone is located in the Hormuz Strait. This phenomenon reflects the general situation of Arabia anticyclone in the days before the start of precipitation in the area between the Hormuz Strait to eastern Arabia and Oman. Thus, the Arabian anticyclone shifts from west to east in the years with early start precipitation from about 15 to 20 days before the start of precipitation, and the western region of the Hormuz Strait to southwestern Iran is freed from the influence of Arabia anticyclones and ridges . Figures 9B and 10B show the geopotential height curves of 700 hPa for the first day of rainfall in ten systems with early autumn precipitation. As can be seen, in all the years when there was early autumn precipitation, Arabian anticyclone was at a constant longitude of 50 degrees east in the range of 22 to 30 degrees north (south of the Strait of Hormuz).

Figure 9.

Figure 10.

Figures 11 and 12 show the horizontal profile geopotential height of 850 and 700 hPa on a fixed latitude of 20 º N passing through the center of the Arabian Peninsula in the range of 20 to 65 º E (west of Egypt to the center of the Oman Sea) for each of the years with Indicates early autumn precipitation. Each curve indicates the position of its geopotential height at 15 days before the start of precipitation. The red curve shows the position of the geopotential height of the first day of precipitation on each of years. As can be seen, in all the years (as shown in the box), the central core of Arabian anticyclone has been moving south and eastward for almost 15 days before since the beginning of the rains. This eastward movement is seen on all days of the start day without exception. (Red curve). These diagrams clearly show the undeniable role of the south and eastward displacements of the Arabian anticyclone in the start of precipitation in the western region of Arabia and the south of Iran. Accuracy of the longitude position of the core (highest geopotential height) and its eastern edge (breaking point of the geopotential height curve) shows that in all cases a large part of the anticyclone is located on the warm waters of the Arabian and Oman Seas. This feature of anticyclone installation is the best pattern for moisture advection in anticyclonic circulation on the Arabian Peninsula and southern Iran.

Figure 11.

Figure 12.

4 Conclusion

Due to its geographical location in relation to the general pattern of atmospheric circulation (Hadley cell) and regional circulation, as well as its proximity to large-scale planetary systems such as the Arabian anticyclone, Iran has no rainfall for part of the year

In most parts of Iran, this period of no or little precipitation coincides with the warm period of the year. This dry period in the southern and southwestern of Iran is slightly longer than other parts of the country. So that this dry and hot period increases to 6 to 7 months of the year and in droughts up to 8 months. But according to the custom and agricultural calendar of Iran, which begins in October and ends in September next year. Precipitation of this period is considered as the crop year for the growth and development of crops. In the cold regions of the country, autumn rains, except for the cultivation of some legumes such as wheat, in other cases are considered as water storage in the soil for spring and summer crops. However, in the southern and southwestern regions of Iran, autumn is the season of cultivation and growth of many crops due to the temperature characteristics. Therefore, early start of precipitation in this region is very useful for agriculture and farming in this region and is very effective in the quantity and quality of crops. Note that this region, in addition to being the center of production of tropical products of the country.

Many of the country's crops, including vegetables, summer vegetables and fruits, are grown in the region for the cold season. This region is also one of the centers of wheat and citrus production in the country.

In the southern region of Iran, due to its proximity to the powerful Arabian anticyclone system and its yearly displacement, following the general and local atmospheric circulation; rainfalls is starts about once or two months later than other parts of the country. Arabian subtropical anticyclone is the most important system for controlling the beginning and end of the rainy season in the region (Lashkari et al., 2017; Jafari and Lashkari., 2020 and Lashkari and Jafari 2021). The results of this study showed that in 11 years out of 36 years of selected rainfall period (1979-2015) that early autumn rainfall occurred. Early rainfall occurs in less than 20 days from October 1st. Two synoptic patterns determine early rainfall in this region. In the first pattern, in the lower layer of troposphere, the dominant systems are a integration of the tow anticyclone of Arabian and Africa and the low pressure of Pakistan. From a few days before the Rainfall start, the Pakistani system covers the whole of eastern and central part of Iran with the northward expansion. This trough extends to the coasts of Caspian Lake. The expansion of this system on Iran is accompanied by the warm advection of southern latitudes on Iran. In contrast, with the northward expansion of the African anticyclone over the Mediterranean Sea and southern Europe, cold currents have advected in anticyclonic Circulation over northeastern Africa. The eastern ridge of this anticyclone is integrated with the Arabian anticyclone of the lower part of troposphere. As the cold dvection continues to the back of the Sudanese system, the thermal gradient created strengthens this thermal low. This geopotential height gradient is especially noticeable in the western side of Sudan low. From the level of 850 hPa and above, with the continuation of the cold advection of the eastern side of African anticyclone, the Suitable background has been prepared for the deepening of the Mediterranean trough and its expansion over the region. So that in the middle layer of troposphere, this trough has expanded to 15 º N (Red Sea and Sudan). This pattern is the most suitable conditions for strengthening the Sudanese system. In this pattern, too, Saudi Arabian anticyclon with an early shift to the east of the Arabian Peninsula; While liberating the southern region of Iran; It has provided suitable condition for the expansion of rainfall systems in the region. At the same time, by being in a suitable position relative to the Oman and Arab warm water seas, it provides the necessary moisture for the southern system. Combined maps of the lower levels of the troposphere illustrate this phenomenon well.

In the second pattern, with the significant northward shift of the Africa anticyclone and the blockade of this system on Central Europe and the cold advection of subtropical latitudes for at least 10 days, it has strengthened the Mediterranean trough. With the expansion of the deep trough on the eastern Mediterranean and northeast of African (Egypt, Sudan and the Red Sea), the necessary dynamic conditions are provided for the formation and strengthening of the two main precipitation systems of this region (Mediterranean cyclone and Sudan low). In this synoptic pattern, the Arabian anticyclone by south and eastward movement; provides suitable conditions for moisture advection into the rainfall systems. As we have seen in this pattern, the Arabian anticyclon is located at all atmospheric levels in the eastern part of the Arabian Peninsula and the Gulf of Aden. In this pattern, the integration of the two cyclonic systems of Sudan and the Mediterranean in the lower level of troposphere and the Arabian anticyclone in the middle level of troposphere is the dominant pattern. In these years, a few days ago, with the movement of the south and eastwards the Arabian anticyclone, the conditions for the entry and expansion of precipitation systems were provided.The results of this study with research results (Lashkari,2002;Karimi Ahmadabadi, 2007; Karimi Ahmadabadi and Farajzadeh, 2011; Karimi et al., 2016) , (Lashkari and Mohammadi, 2015; Lashkari et al., 2018) is consistent.

As mentioned, in the second part of the research, the horizontal profile of the geopotential height at different levels on the Arabian Peninsula is drawn. Figures 10a and B on a fixed meridian 50 degrees east and the width of the variable from zero to 70 degrees north well show the position of the northern end of the Arabian anticyclon, The diagram showed that the anticyclon was completely closed in the range of 30˚n.The steep slope of the geopotential height curves well shows the end of the northern edge of the anticyclone on the latitude of 30 º N, which is located in the Hormuz Strait. Examination of the longitudinal profile in the days before the stary of precipitation in each of the sample years with early start precipitation at the levels of 850 and 700 hPa also showed that in all years at least 15 days before the start of precipitation the central core of Arabian anticyclone in the range between 35 Up to 50 and generally between 40 º and 55 º E. The interesting phenomenon is that the eastern edge of the anticyclone in all samples, especially at the level of 850 hpa, is located on the warm waters of the Arabian and Oman Seas. As the red curves show, on the first day of precipitation, all or a large part of the anticyclone zone is located on the sea. This pattern of establishment is the most suitable conditions for the penetration of moisture into the transmission systems from the south (l Sudan low and the Red Sea trough). As a result, the eastward movement of Arabian anticyclon is the most important factor in creating the necessary conditions for the entry of rainfall systems on the Arabian Peninsula and West Asia and the start of early precipitation.

Declarations

Theoretical and Applied Climatology

Aug 11, 2021

Dear Prof. Dr. Carlo Baco

I would like to submit the manuscript entitled "**Analysis of behavior pattern and thermodynamic structure of Arabian Anticyclone in early onset of precipitation in south and southwest of Iran**" by Hassan Lashkari and Zainab Mohammadi to be considered for publication as an original article in the Theoretical and Applied Climatology.

We declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere. This manuscript is part of the results of the Ph.D. dissertation of the corresponding author, which has been defended at Shahid Beheshti University (SBU) under the supervision of the first author.

Funding: there has been no significant financial support for this work that could have influenced its outcome. Conflicts of interest/Competing interests: We know of no conflicts of interest associated with this publication and we have no potential conflict of interest in relation to the study in this paper.

Availability of data and material: All data and material used in this article is available and could be provided.

Code availability: 'Not applicable'

As Corresponding Author, I confirm that the manuscript has been read and approved for submission by all the named authors.

We hope you find our manuscript suitable for publication and look forward to hearing from you in due course.

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Conflict of interest

The authors declare that they have no conflict of interest.

Authors Contribution: "Both (All) authors have contributed equally to the work"

Ethics approval: "The data used in this article were free"

Consent to participate: 'Not applicable'

Consent for publication: we give our consent for the publication of identifiable details of the manuscript in the Theoretical and Applied Climatology, which could be include tables, figure **and other details.**

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Tables

Table 1. Position of selected stations based on the length of the precipitation period

Station	x	y	h	Station	x	y	h
Aligoodarz	49.42	33.24	2022	Siri Island	54.29	25.53	4.4
Omidieh	49.39	30.46	34.9	Khoram Abad	48.17	33.26	1147.8
Ahwaz	48.4	31.2	22.5	Dezfool	48.28	32.24	143
Ilam	46.26	33.38	1337	Dogonbadan	50.49	30.2	726
Abadan	48.15	30.22	6.6	Ramhormoz	49.36	31.16	1505
Abadeh	52.4	31.11	2030	Sharkord	50.51	32.7	2048.9
Aghajari	49.4	30.46	27	Shiraz	52.36	29.32	1484
Boroojen	51.18	31.59	2260	Safiabad Dezfool	48.25	32.16	82.9
Bostan	48	31.43	7.8	Fasa	53.41	28.58	1288
Bandar Abbas	56.22	27.13	9.8	Koohrang	50.7	32.26	2285
Bandar Lengeh	54.5	26.32	22.7	Kish	53.59	26.3	30
Coastal Bushehr	50.49	28.54	8.4	Lordegan	50.49	31.31	1580
Coastal Bushehr	50.49	28.58	9	Masjed Soleiman	49.17	31.56	320.5
Jask	57.46	25.38	5.2	Minab	57.5	27.6	29.6
Abumus Island	54.5	25.5	6.6	Yasooj	51.33	30.41	1816.3

Figures

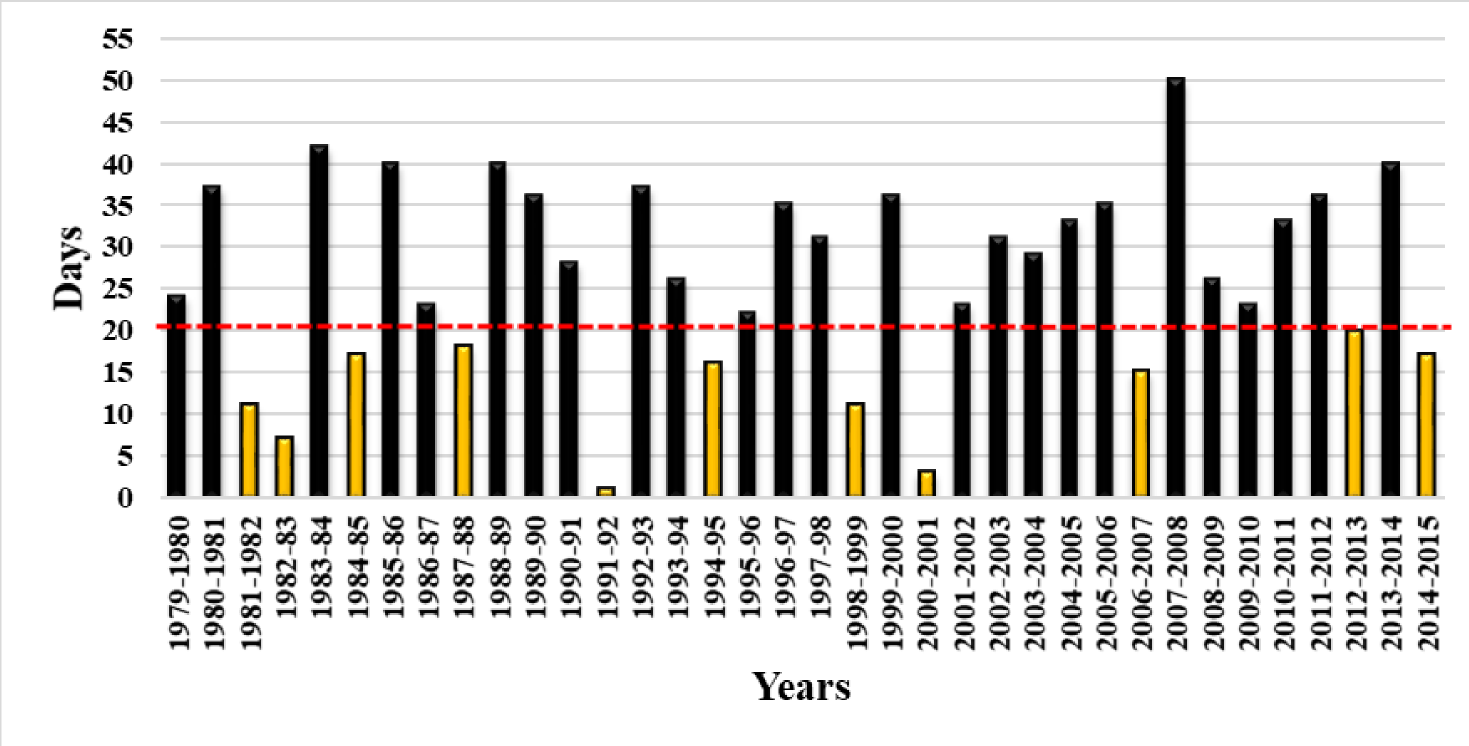

Figure 1

Number of days away from the origin of counting (September 22) for the day of precipitation. Orange lieutenants represent early starting years.

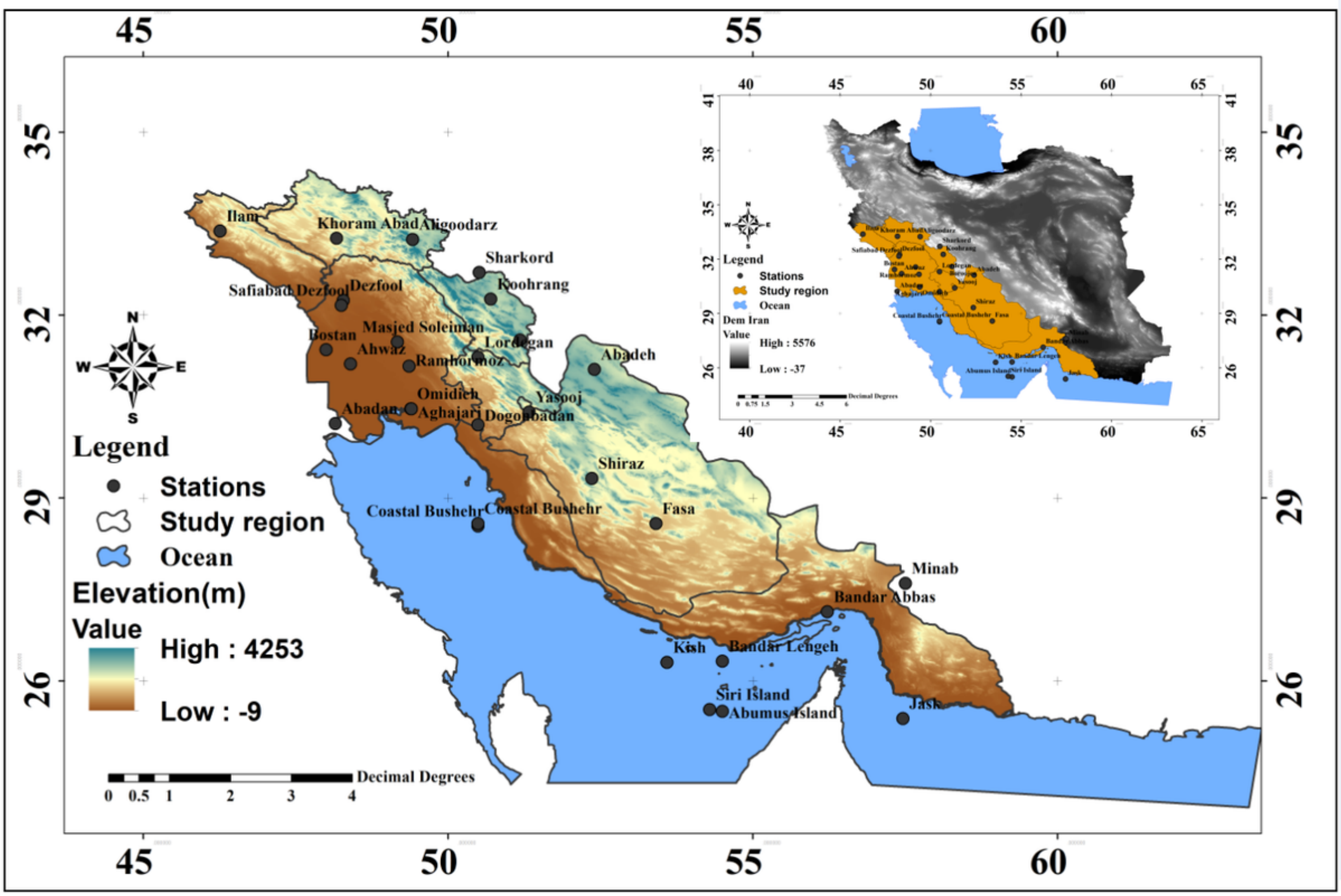

Figure 2

Location of stations and study area in the south and southwest of Iran

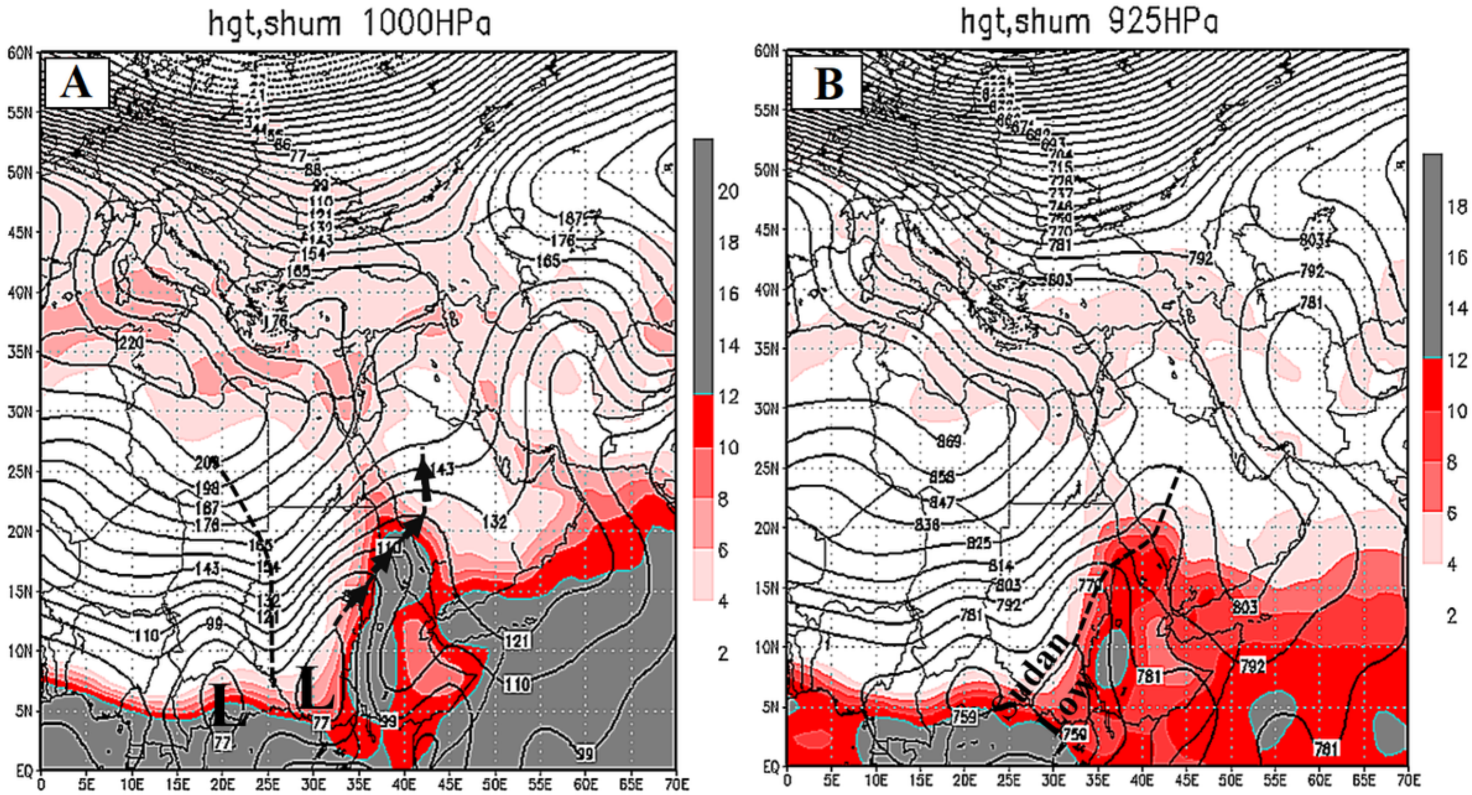

Figure 3

Combined map of geopotential, specific humidity at the level of 1000 hPa (A) and 925 hPa (B) in the first pattern of early autumn precipitation in southern and southwestern Iran.

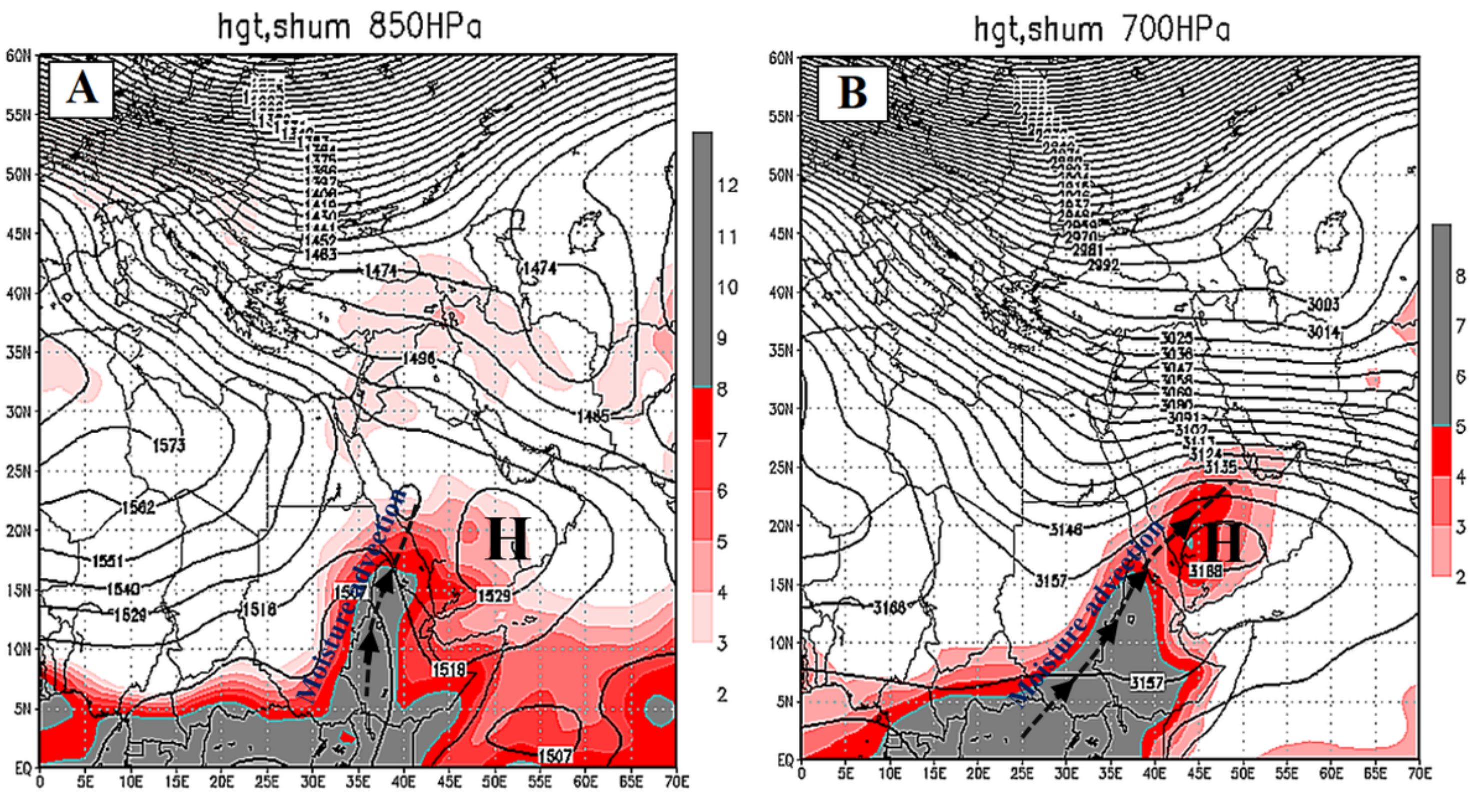

Figure 4

Combined map of geopotential, specific moisture for the level of 850 hPa (A) and 700 hPa (B) in the first pattern of early autumn precipitation.

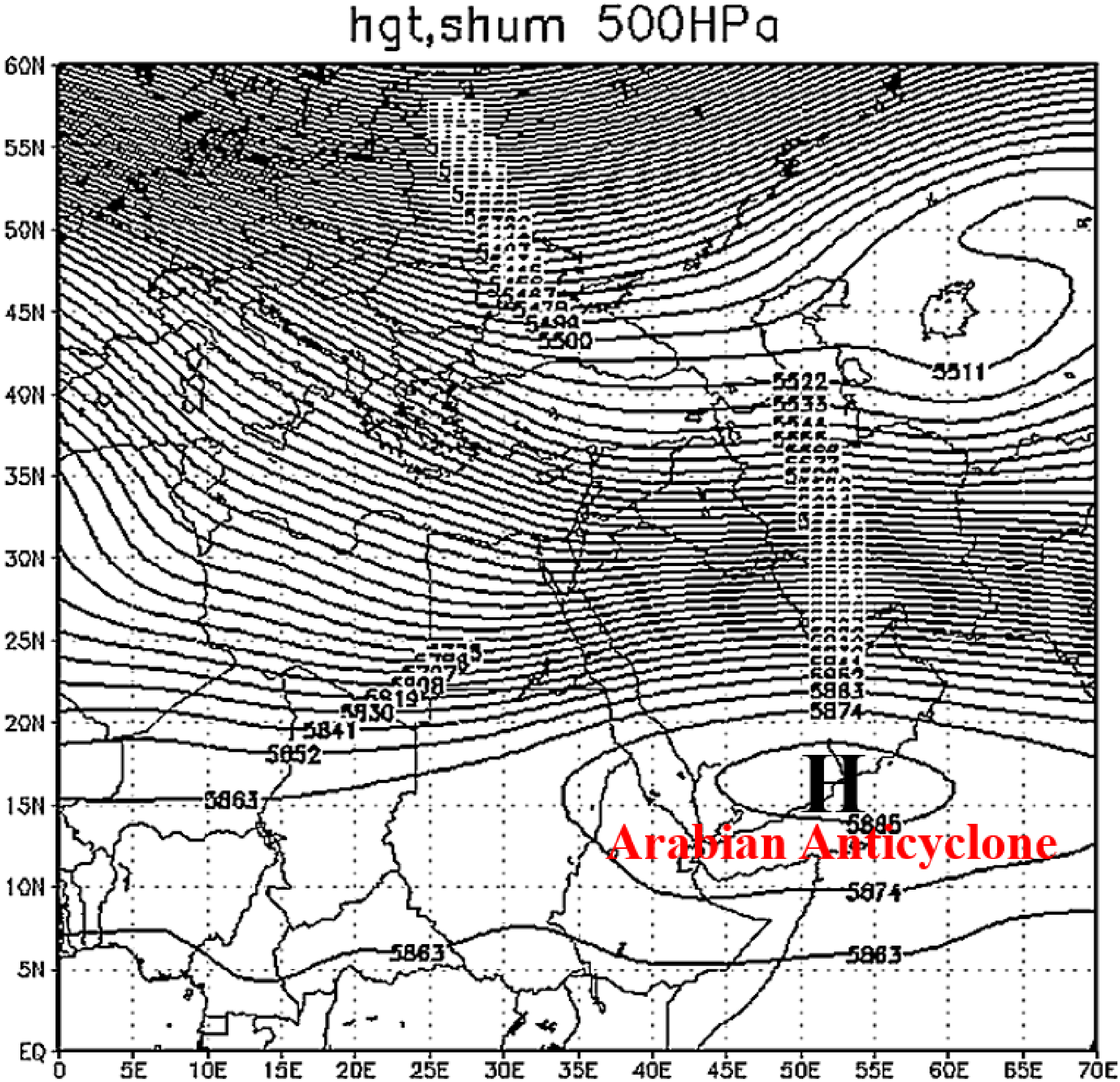

Figure 5

Composite map of geopotential, for the level of 500 hPa in the first pattern of early autumn precipitation.

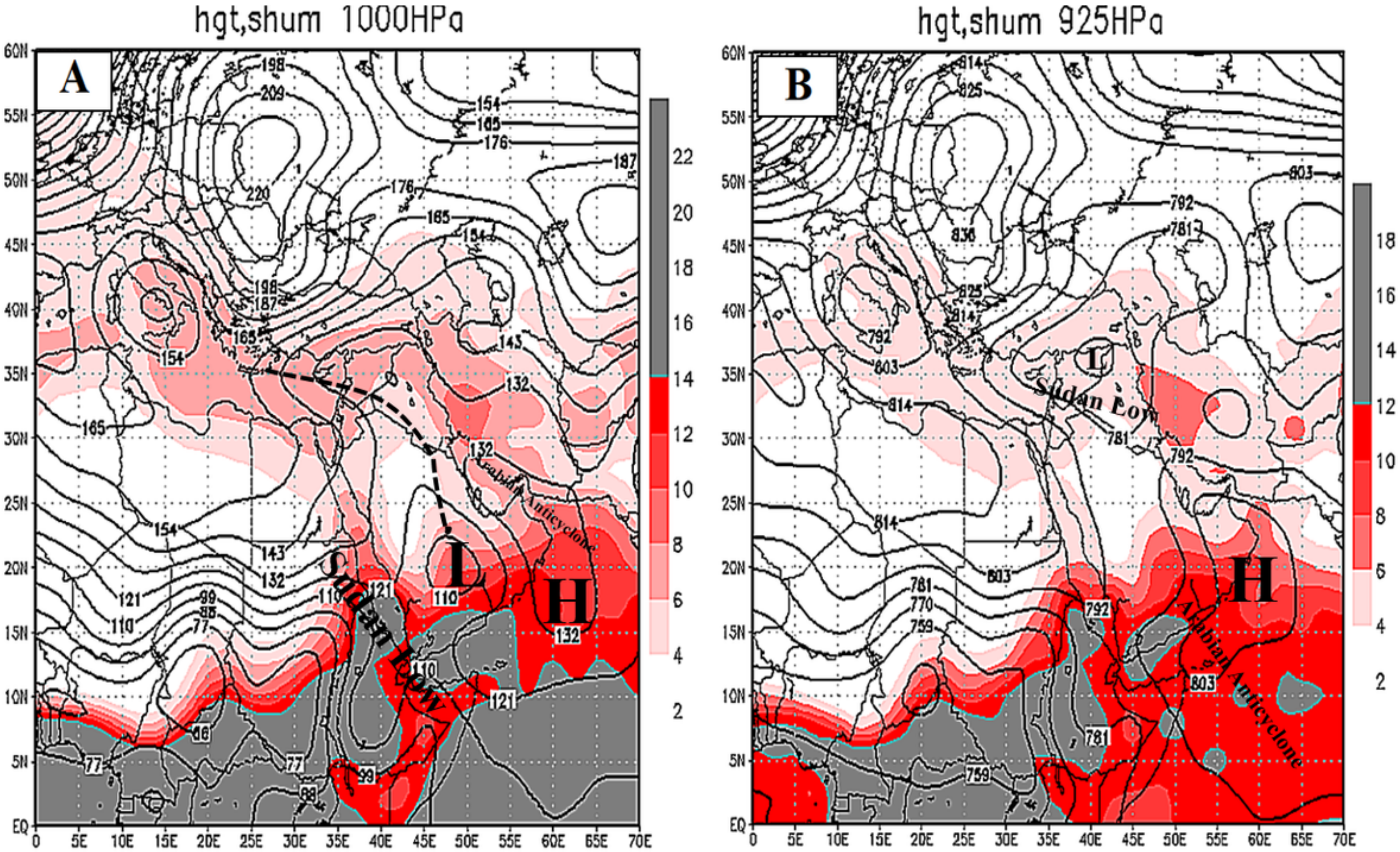

Figure 6

Combined map of geopotential, specific humidity level 1000 (A A) and level 925 hPa (B) in the second pattern of early autumn precipitation.

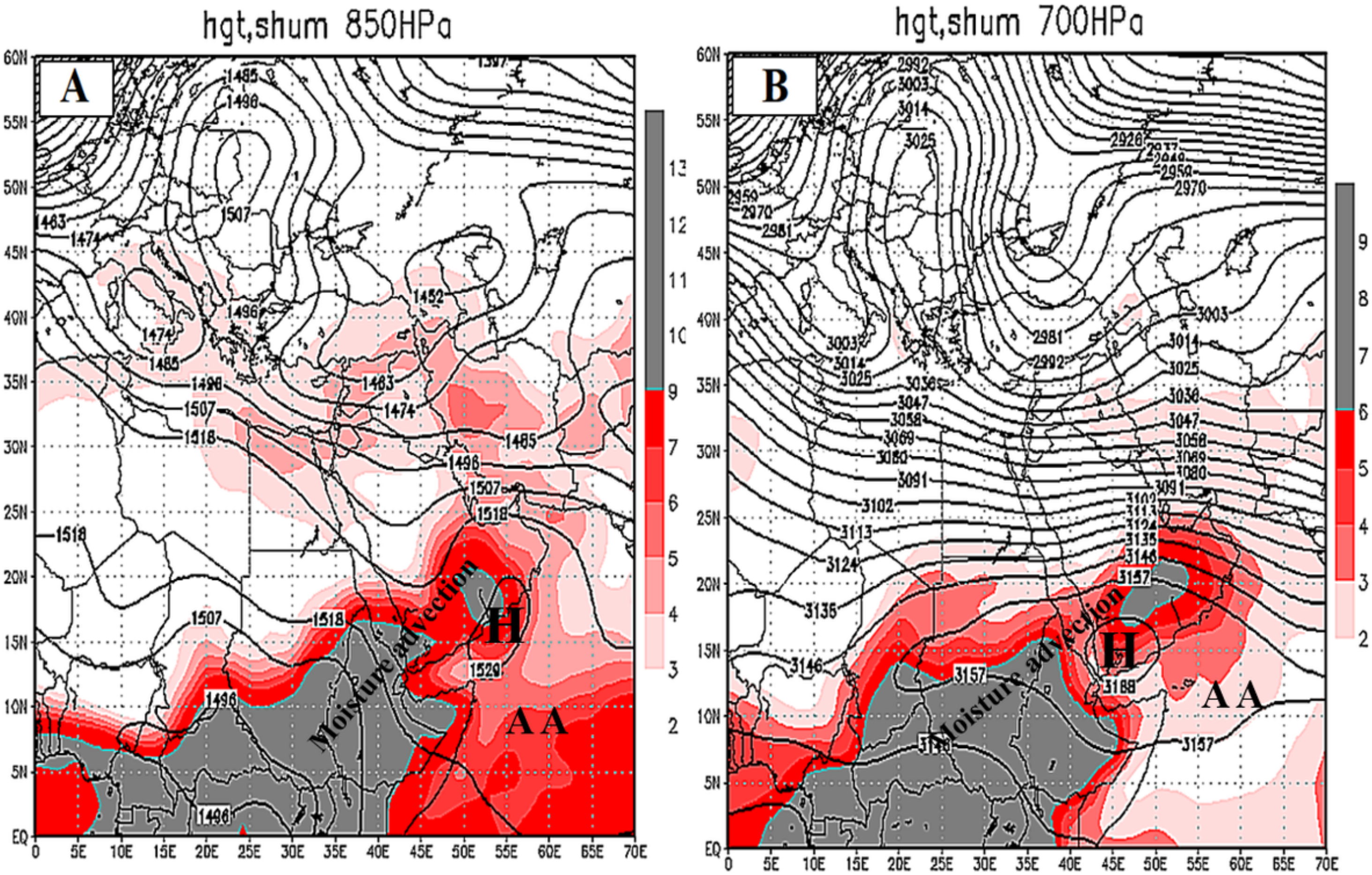

Figure 7

Combined map of geopotential, specific moisture level 850 (A) and level 700 hPa (B) in the second pattern of early autumn precipitation

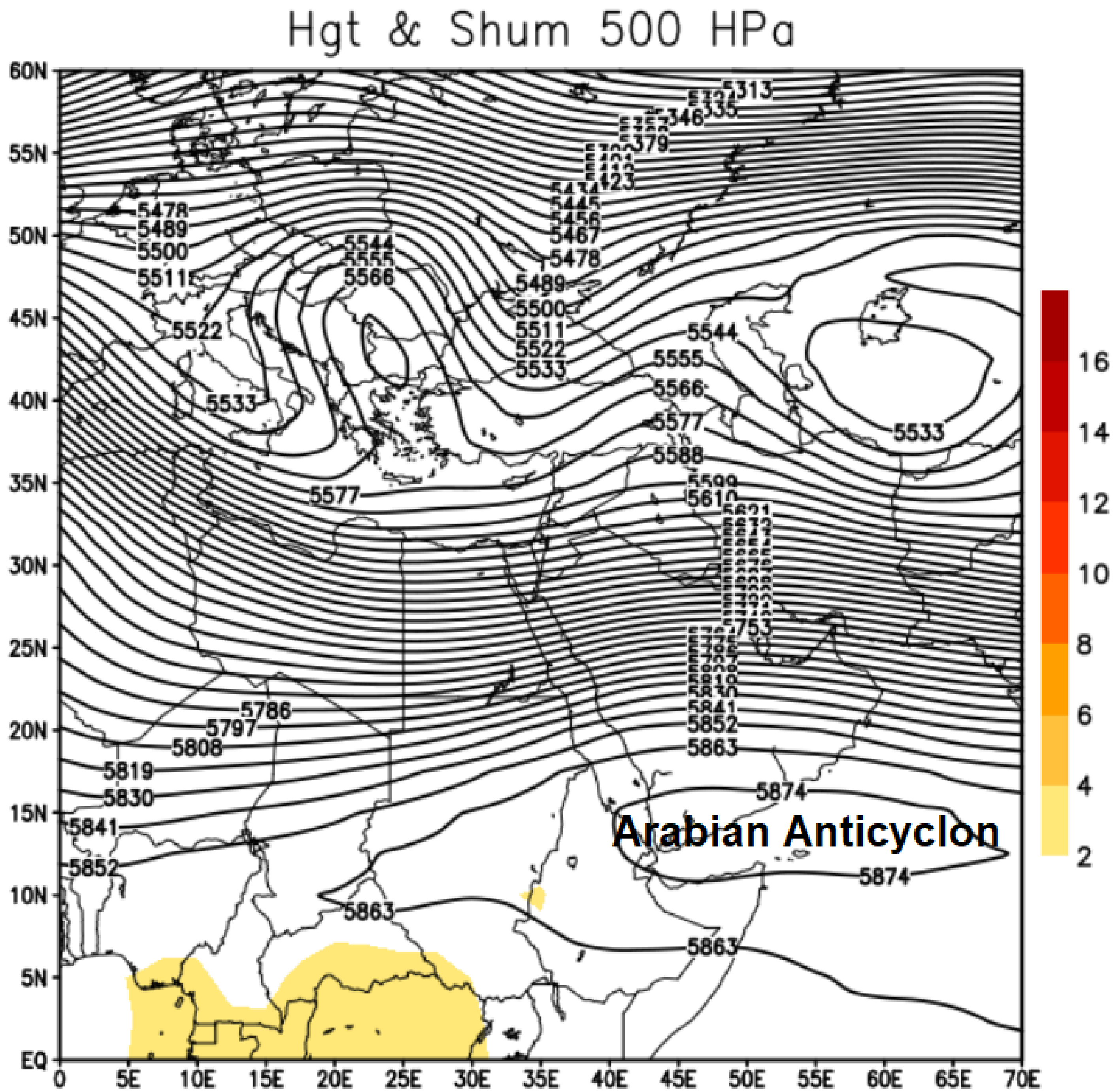

Figure 8

Combined map of geopotential, specific humidity and flow level of 500 hPa in the second pattern of early autumn precipitation

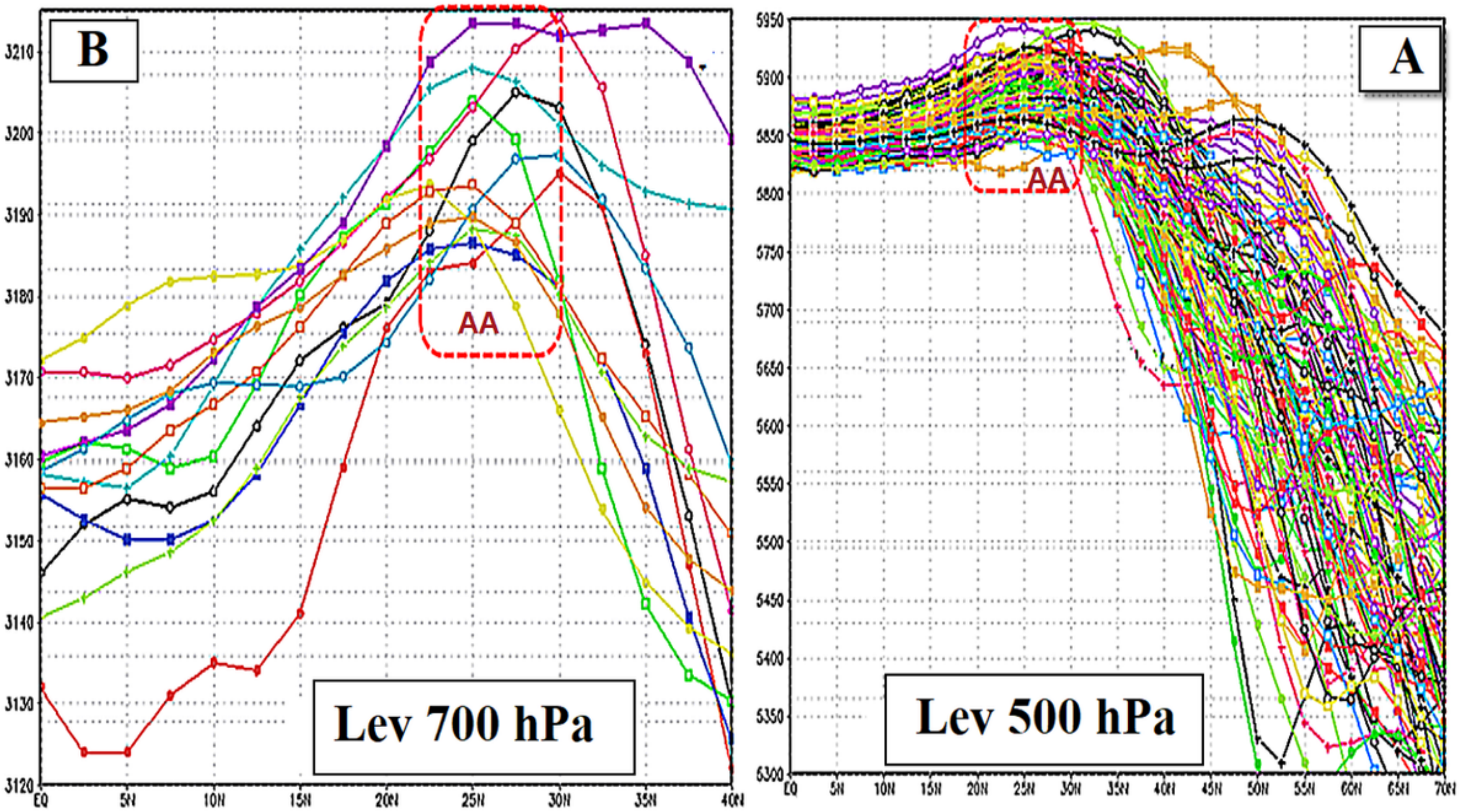

Figure 9

Horizontal profile of geopotential height (south to north at 50 º E longitude(at levels A) 500 hPa for 15 days before the early start precipitation samples and B) 700 hPa for the first day of rainfall Ten early precipitation samples in the first pattern.

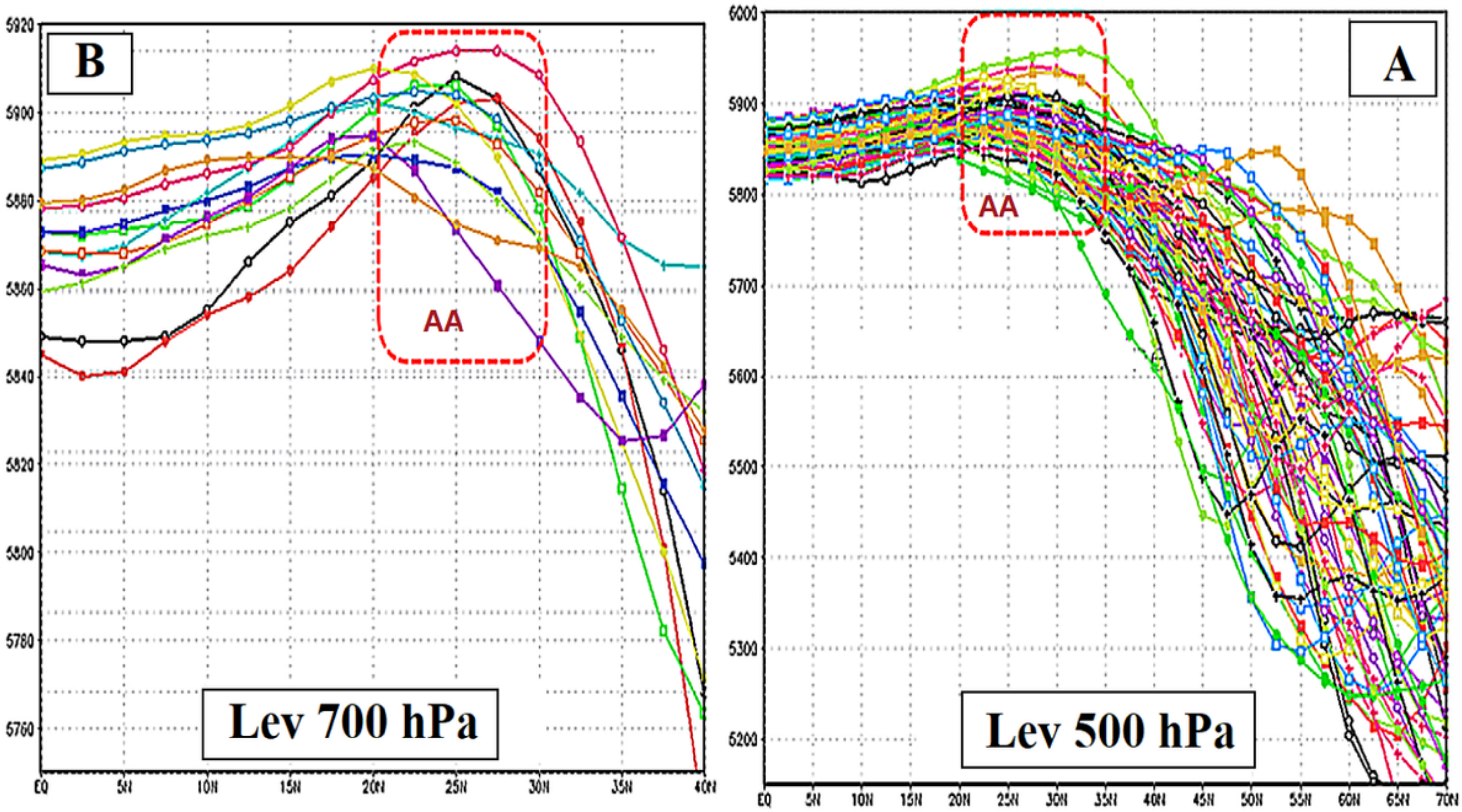

Figure 10

Horizontal profile of geopotential height (south to north at 50 º E longitude) at levels A) 500 hPa for 15 days before the early start precipitation samples and B) 700 hPa for the first day of rainfall Ten early start precipitation samples in the second pattern.

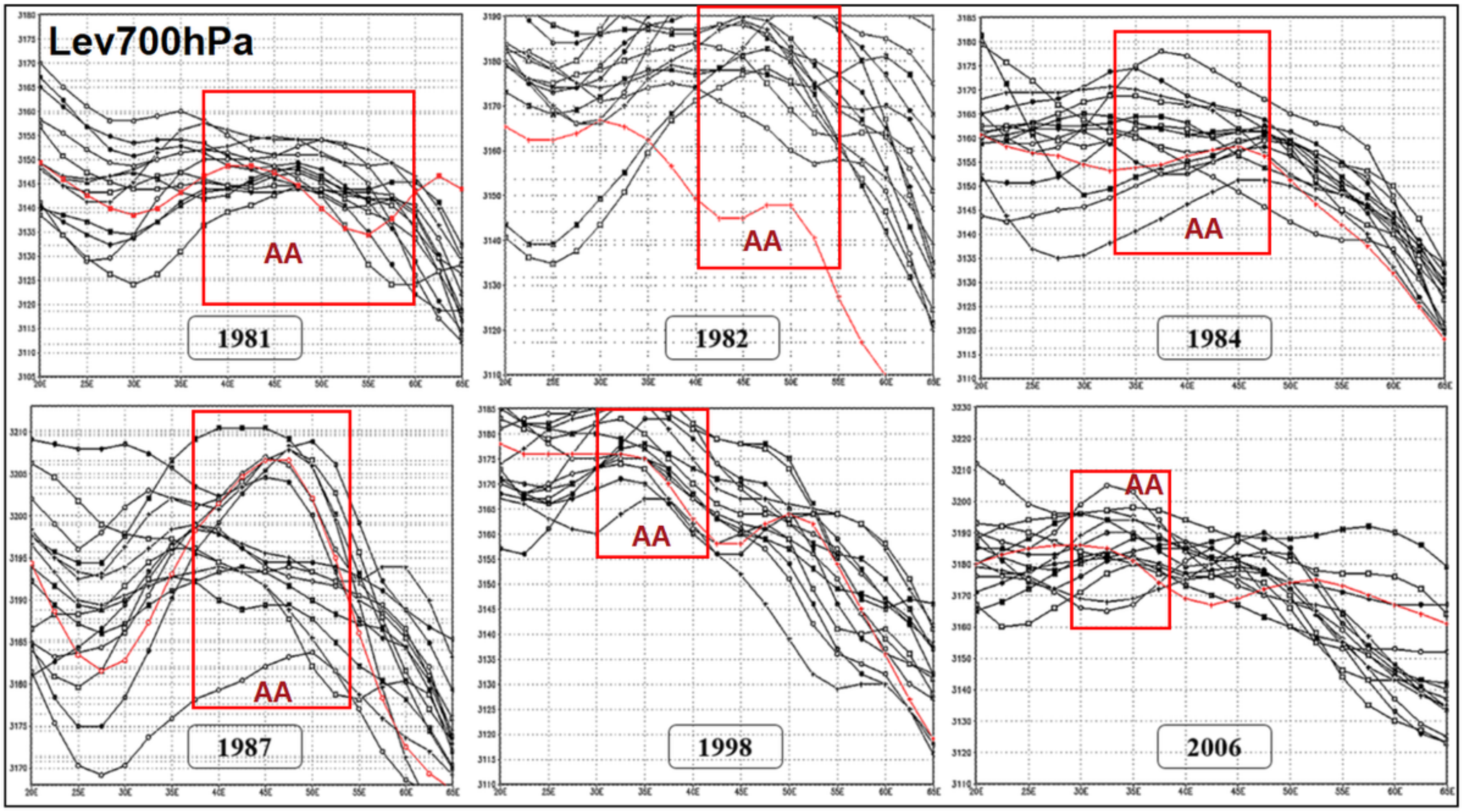

Figure 11

Horizontal profile of geopotential height (west to east on a constant latitude of 20 º N) at 700 hPa for 15 days before the start of precipitation (black curves) and the first day of precipitation (red curve) in each of the early start precipitation samples.

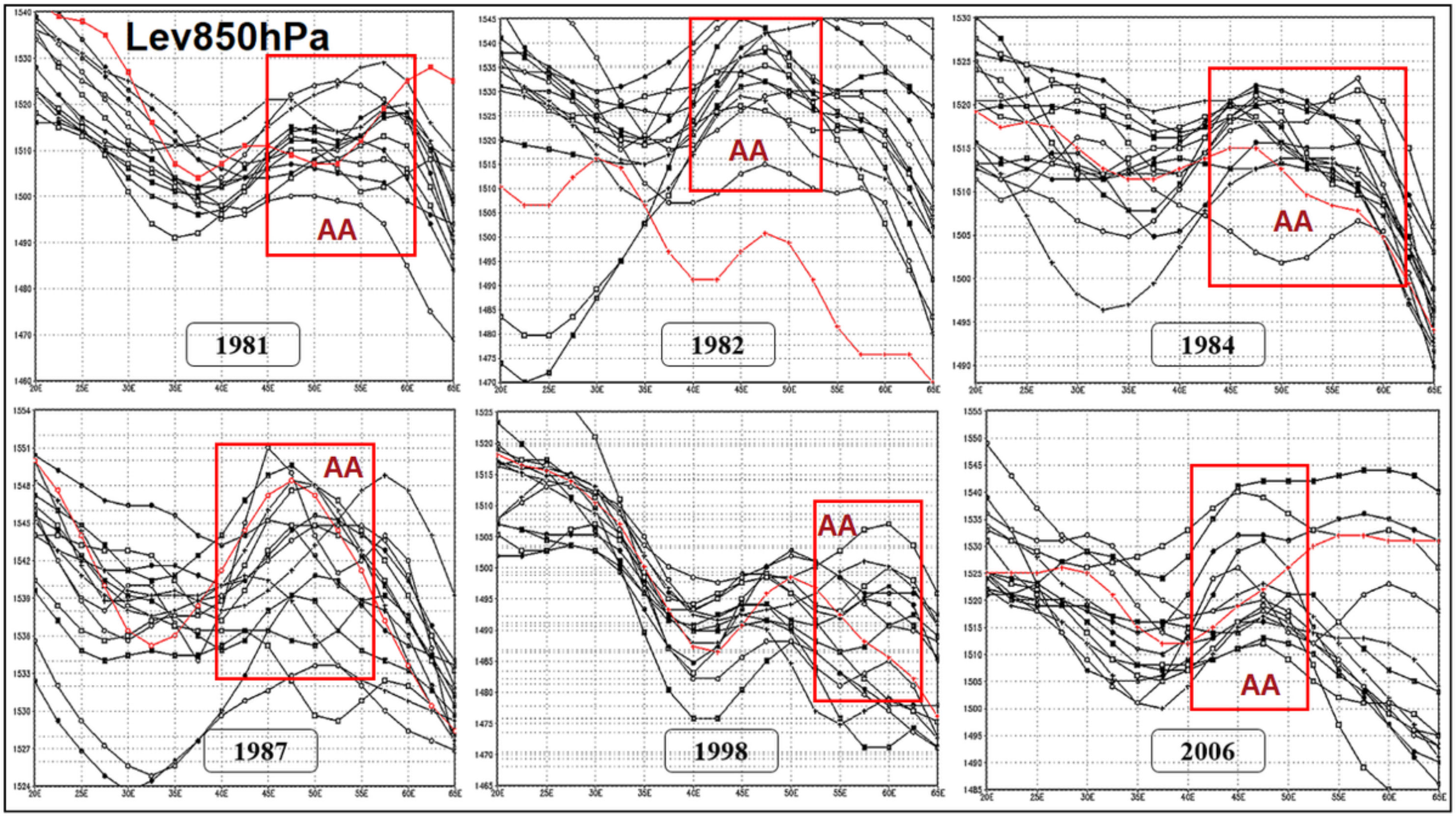

Figure 12

Horizontal profile of geopotential height (west to east on a constant latitude of 20 º N) at 850 hPa for 15 days before the start of precipitation (black curves) and the first day of precipitation (red curve) in each of the early start precipitation samples.