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The Impact of Westward Currents in the Indian Ocean on Precipitation in Western and Southwestern Iran

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ABSTRACT

In this study, to identify the source of moisture for the widespread and heavy rainfall that occurred on 21 and 22 January 2007 in the western and southwestern regions of the country. To achieve this, we conducted a synoptic and thermodynamic analysis of the rainfall. Daily precipitation data from 45 synoptic stations across 7 provinces were obtained from the Iranian Meteorological Organization and analyzed. First, we identified the rainfall through data from ground stations. Then, using upper atmosphere data and relevant maps, we analyzed the widespread and heavy rainfall in the west and southwest of the country. The results show that on the day of the onset of precipitation, the Sudanese and Mediterranean low-pressure troughs merged on the eastern edge of the Mediterranean, and on the day of the peak of precipitation, the Sudanese low-pressure system independently caused the rainfall of this period. The study of moisture flow maps showed that the Indian ocean and Red, Oman and Persian Gulf Seas played a major role in strengthening and providing moisture to the Sudanese low-pressure system during the occurrence of precipitation. At high levels, on the day of the onset of precipitation, the establishment of blocking in the west of the study area and the displacement of the trough associated with it over the study area and the expansion of the trough axis resulting from it to southern Arabia and the location of the western half of Iran in the east and in front of the trough and its association with low surface pressure have advanced simultaneously. The establishment of the subtropical jet stream on the front of the trough and high divergence played a major role in strengthening the Sudanese low-pressure system, sucking moisture from southern water resources, and as a result, widespread rainfall in the west and southwest of the country.

1. Introduction

Synoptic climatology is a science that studies the relationship between atmospheric circulations and the surface environment of a region (Masoudian, 2006, 1). Synoptic and thermodynamic analysis of atmospheric circulation patterns, in identifying factors affecting the occurrence and behavior of precipitation, provides the possibility of planning based on it. This kind of attention to precipitation is of particular importance, especially in various areas of a water-scarce land such as Iran, whose water resources rely on precipitation and are accompanied by an increasing demand from a growing population (Asakereh and Razmi, 2011, 138). Since atmospheric instability and precipitation occurrence in southwestern Iran are generally affected by Sudanic systems, therefore, studying the dynamics of the formation, evolution and decline of this system, predicting and knowing the status of precipitation and planning for the exploitation of these precipitations as reserves for the reservoirs of the region's dams, can be effective and efficient in the management and planning of water resources. (Mohammadi et al., 2012, 8). Numerous studies have been conducted in Iran and around the world with different approaches and goals regarding synoptic and thermodynamic analysis of heavy precipitation, which shows the importance of studies and their applications. Among them, the following can be mentioned.

(Littman, 2000, 170) classified the pressure and geopotential height data at the 500 hectopascal (hPa) level using cluster analysis and examined the relationship of the resulting weather types with Mediterranean precipitation. (Kahn et al., 2004, 881) In "Interpretation and study of changes in hourly heavy precipitation in Tokyo from 1980 to 1999", they concluded that heavy precipitation occurred in the 1940s and 1990s. (Siebert et al., 2005, 16) studied the regional and synoptic patterns of heavy precipitation in Australia and defined seven synoptic patterns for heavy precipitation in Australia using the path ranking method using daily precipitation from 31 climate stations during the years (1993 to 1997). (Mahras et al., 2004, 4) studied the circulation patterns of 500 hPa in Greece. In his research, he identified six anticyclonic patterns, eight cyclonic patterns, two mixed cyclonic and anticyclonic patterns, and four special weather patterns. (McGarrick et al., 1998, 116) The term plume has been used to mean the explosion of tropical moisture from the tropical part of equatorial Africa and the Gulf of Guinea towards the Middle East and southern Iran, which is a kind of attention to the interaction of the tropical and extratropical regions; that is, the location of the mid-latitude trough axis at the exit of the subtropical jet stream causes clouds from the tropical region of Africa to the Middle East and especially southwest Iran, causing heavy and flooding rainfall. (Keith Busher, 1994, 77) has mentioned something similar for the subtropical region of North America. The transfer of clouds from the equatorial part of Africa and the Gulf of Guinea to the Middle East and southwestern Iran and the occurrence of heavy rainfall due to the location and shape or type of curvature of the subtropical jet stream axis and the unification of the mid-latitude trough axis at the outlet of the subtropical jet stream in the northern Red Sea has been demonstrated by examining satellite images of several large storms and observing a very high density of clouds over an area of several thousand kilometers from the subtropical convergence belt (equatorial Africa) towards the Caspian Sea (Dayan and Abramsky, 1983, 63).

(Sabziparvar, 1991, 9) has studied the synoptic of flood-causing systems in southwestern Iran. He considers the main factor of heavy and flood-causing rainfall in southwestern Iran to be the presence of a deep trough at high level (so that the trough axis extends southward to the south of the Red Sea). According to their research, the dynamic Mediterranean low pressure, while moving east and southeastward, through the injection of cold air into the low pressure of the Sudan region, causes this low pressure to become dynamic and a combined system called the Mediterranean-Sudanese system is formed, which is an example of the interaction of a polar air mass with a tropical air mass and brings relatively significant rainfall in Iran. (Lashkeri, 2003) has studied the Sudanese low pressure and its role in rainfall in the south and southwest of Iran. He introduces the Sudanese low pressure system as one of the elements of the general atmospheric circulation in North Africa, which is formed over western Ethiopia and Sudan most of the year, and four general patterns resulting from the arrangement of the Siberian systems, the North African anticyclone, and the Arabian Peninsula, the North African trough, and the Sudanese low pressure in the lower and middle levels of the atmosphere, lead to the occurrence of heavy rainfall in the south and southwest of Iran. (Mafidi, 2004, 92) introduced a synoptic study of flood-causing rainfall in the Middle East, which appeared from the convergence zone on the western side of the Ethiopian plateau and then moved towards Iran or the eastern Mediterranean under the influence of the topographic factors of the Red Sea and the thermodynamic and dynamic conditions governing the atmosphere of the surrounding areas. (Alijani, 2002, 131) used the calculation of vorticity to identify the rain-causing masses of Tehran. He stated that the effect of the 500 hpa level is more important than other levels and that cyclone types produce heavier rainfall.

(Mafidi and Zarrin, 2005, 135) studied the effect of Sudanese low-pressure systems on the occurrence of heavy and flood-causing rainfall in Iran from a synoptic perspective and stated that the main role in flood-causing rainfall is attributed to the influence of the polar vortex at the level of 500 hPa, which acts as the main source of turbulence for the emergence of anomalous circulation patterns and strengthening of the Hadley cell or subtropical jet over the Mediterranean and North Africa. (Masoudian, 2005, 163) analyzed the Karun flood rainfall by analyzing the mid-level circulation patterns and showed the role of Mediterranean thoughts in causing such rainfall. (Omidvar, 2007, 97) studied and analyzed the synoptic and thermodynamic conditions of rainfall occurrence in the Shirkuh region and concluded that the rainfall in this region is caused by three synoptic systems: 1- The establishment of Sudanese low pressure over the Arabian Peninsula; 2- Combined Sudanese and Mediterranean systems; 3- Mediterranean systems. Akbari et al, 2016: 591 In examining the role of the Blocking system in the January 2008 precipitation event in southeastern Iran, they showed that during the precipitation, the penetration of the Sudanese low pressure at the ground surface and the Blocking system in the middle atmosphere caused the dynamics of low pressure and the occurrence of torrential rainfall in the region. (Ghavidel & Jafari, 2020: 17) In analyzing the extremely heavy rainfall on April 1, 2019 in western Iran, they concluded that at the ground surface, the presence of low pressure in northern Arabia and at mid-levels of the troposphere, the establishment of a cut-off low blocking in western Asia provided the conditions for the spread of unstable flows from the Red Sea and Mediterranean to the western half of Iran. (Ghassabi etal, 2022: 17) In examining the effects of daily circulation patterns of the troposphere on dry and wet events in Iran, they found that the expansion of south and southwest currents from the Red Sea creates conditions for the expansion of low-pressure centers from the south of the Red Sea to southern Turkey and the western parts of Iran, resulting in most precipitation occurring in the western half of the Zagros Mountains. Zakizadeh et al. (2018: 31) also considered the establishment of a 65 m/s jet stream at a level of 300 hpa in the southern half of Iran, along with the formation of a cold trough over the Caspian Sea, to be the reason for the occurrence of heavy and widespread precipitation in Iran. Omidvar et al. (2018: 35) studied the heavy rainfall of December 24, 2014 in Kohgiluyeh and Boyer Ahmad provinces and found that the formation of a blocking phenomenon over the Mediterranean Sea and its deep thought over Iraq, resulting in the fall of cold air over the region and the transfer of warm southern air, caused heavy rainfall on this day over the studied region. According to Pazhoh and Darand (2024), the concentration of precipitation in Iran has increased in recent years, and the concentration of precipitation in the western and southwestern regions of the country was due to a decrease in the frequency of rainy days and an increase in the intensity of heavy rainfall. The purpose of this research is to conduct a synoptic and thermodynamic analysis of the causes of widespread and heavy rainfall in the western half of the country in relation to low-pressure systems and to analyze the moisture role of water resources adjacent to Iran, the results of which will help to further understand the rain-generating systems in these regions.

2. Data and Methods

This study utilized two sets of data to analyze the widespread and heavy rainfall that occurred on 21 and 22 January 2007 in western and southwestern Iran. These data sets include ground station data and upper atmosphere data. The ground station data consist of daily precipitation measurements for 21 and 22 January 2007, obtained from the Machine Services Department of the Iran Meteorological Organization. The upper atmosphere data comprise reanalyzed data for geopotential height, sea level pressure, zonal wind, meridional wind, and omega, sourced from the National Center for Environmental Prediction in Colorado. The jet stream map was created at the 250 and 300 hPa levels, while additional maps were produced and analyzed at the 1000, 850, 700, and 500 hPa levels. Figure 1 illustrates the distribution of stations in the study area. Furthermore, the total 24-hour rainfall on 21 and 22 January 2007 for more than 45 stations located in the western and southwestern regions of the country is presented in Table 2. The rainfall began in the southwest on 21 January and peaked on 22 January, with significant amounts recorded at stations such as Kohrang (55.8 mm) in the southwest, Doroud (50 mm), and Azna (35 mm) in the west of the region. Table 1 details the geographical locations of the stations in the studied area.

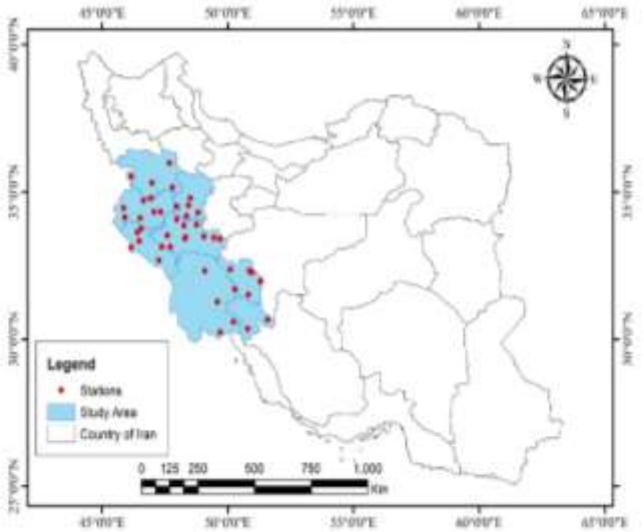

Figure 1. Study area and selected stations

3. Results and Discussion

Table 2 shows the 24-hour rainfall at selected stations, with the peak rainfall occurring on January 22, 2007, and the highest rainfall was recorded at Koohrang station with 55.8 mm due to the influence of the mountainous factor, followed by Doroud and Yasuj stations with 50 and 33 mm.

Table 1. Geographical location of stations in the study area

Stations	Height	lon		lat		Stations	Height	lon		lat	
Bijar	1883	47	37	35	53	**Azna**	1871.9	49	25	33	27
Qorveh	1906	47	48	35	10	**Ashtar**	1567.2	48	15	33	49
Marivan	1286.8	46	12	35	31	**Badrabad**	1154.8	48	16	33	26
Sanandaj	1373.4	47	0	35	20	**Boroujerd**	1629	48	45	33	55
Kamyaran	1404	46	56	34	48	**Boroujen**	2197	51	18	31	57
Hamedan	1741.5	48	32	34	52	**Yasuj**	1831.5	51	41	30	50
Malayer	1777.8	48	51	34	15	**Dogonbadan**	699.5	50	46	30	26
Tuysarkan	1783.2	48	26	34	33	**Lordegan**	1580	50	49	31	31
Nahavand	1680.9	48	25	34	9	**Farkhshahr**	2065	50	56	32	18
Ravansar	1379.7	46	39	34	43	**Kuhrang**	2285	50	7	32	56
Sarpol	545	45	52	34	27	**Shahrkurd**	2048.9	50	51	32	17
Kermansha	1318.6	47	9	34	21	**Dhadiz**	1457	50	16	31	43
Kangavar	1468	47	59	3	30	**Lali**	365	49	6	32	20
Islamabad	1348.8	46	28	34	7	**Behbahan**	313	50	14	30	36
Gilan Gharb	816	45	56	34	8	**Hindijan**	3	49	44	30	17
Sararud	1361.7	47	18	34	20	**Ramhormoz**	150.5	49	36	31	16
Dorud	1522.2	49	0	33	31	**Dareshahr**	670	47	24	33	8
Aligudarz	2022	49	42	33	24	**Dehloran**	232	47	16	32	41
Khorramabad	1147.8	48	17	33	26	**Ilam**	1337	46	26	33	38
Kohdasht	1197.8	47	39	33	31	**Lomar**	850	46	50	33	34
Noorabad	1859.1	48	0	34	3	**Mehran**	150	46	11	33	7
Poldukhtar	713.5	47	43	33	9	**Sarabeleh**	1045	46	34	33	47

Table 2. Total 24-hour precipitation of the studied stations

row	Station name	Total 24-hour p in mm 21 Jan	22 Jan	row	Station name	Total 24-hour p in mm 21 Jan	22 Jan	row	Station name	Total 24-hour p in mm 21 Jan	22 Jan
1	**Borujen**	3	13	**17**	**Doroud**	0	50	**33**	**Sarabeleh**	0.8	2
2	**Yasuj**	7	33	**18**	**Amanabad**	0	24	**34**	**Badrabad**	5.3	21.4
3	**Dogonbadan**	4	20	**19**	**Khoramabad**	5.5	24.4	**35**	**Borojerd**	4	28
4	**Lordegan**	5	53	**20**	**Kuhdasht**	9	23	**36**	**Nahavand**	3.5	19.3
5	**Farkhshahr**	0	13	**21**	**Noorabad**	2	19	**37**	**Kamiaran**	0	3
6	**Kuhrang**	6	55.8	**22**	**Poldokhtar**	12.5	27	**38**	**Marivan**	1	0.2
7	**Shahrkurd**	4	10.4	**23**	**Hamedan**	3	6.2	**39**	**Sanandaj**	1	0.4
8	**Dhadiz**	0	25	**24**	**Malayer**	5	10.4	**40**	**Ravansar**	2	0
9	**Lali**	1	26	**25**	**Twiserkan**	1.1	5.1	**41**	**Sarpol**	6	0.4
10	**Behbahan**	2	10	**26**	**Aligudarz**	1	22	**42**	**Kermansh**	2.9	7
11	**Hindijan**	0	8	**27**	**Azna**	0	35	**43**	**Kangavar**	7	11.4
12	**Ramhormoz**	2	5.2	**28**	**Dareshahr**	13	23	**44**	**Islamabad**	1.2	11.6
13	**Bijar**	0	5	**29**	**Dehloran**	11	8	**45**	**Gilangharb**	3.1	10
14	**Qorveh**	0.7	1.5	**30**	**Ilam**	3.3	4.8				
15	**Sararud**	0.2	9.1	**31**	**Lomar**	5.5	6				
16	**Aleshtar**	0	16	**32**	**Mehran**	7	15				

3.1. Synoptic and dynamic conditions of the first day of precipitation on 21 January 2007

As you can see in the sea level pressure map in Figure 2, an inverted low pressure with a pressure of 1005 hpa is closed on the eastern edge of the Mediterranean, which has formed a Sudanese-Mediterranean integrated system that covers from Sudan to northwest Iran, and western Iran is located in the eastern half of this integrated system. And the center of this low pressure coincides with the upper atmosphere trough.

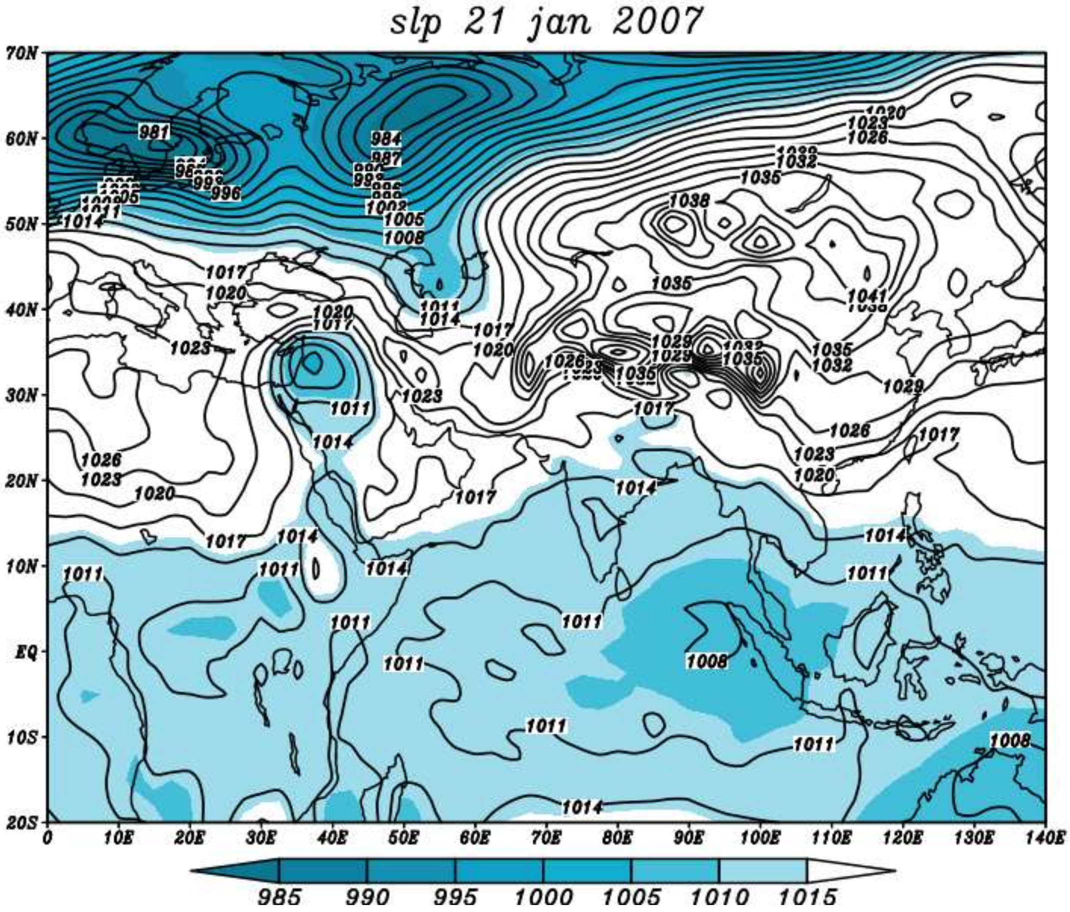

Figure 2. Sea level pressure map on January 21, 2007, one day before the peak of precipitation

In the 850 hPa height map in Figure 3, it is observed that a trough with 1395 geopotential meters is closed on the eastern edge of the Mediterranean Sea, which has a south-north curvature from the south of the Red Sea to the eastern edge of the Black Sea. Western Iran is located on the eastern edge of the trough and in front of it. At the 700 hPa level in Figure 4, the trough located on the eastern edge of the Mediterranean, which is a Cutoff Low, has deepened compared to the 850 hPa level, and the southern limit of this strong cyclone has extended to Sudan, where the study area (western Iran) is located in front of the trough that advects warm and humid air. The study area is currently under the influence of the ridge resulting from the high over Arabia, which plays the role of feeding moisture into the Sudanese system. In the omega map of the 1000 hPa level in Figure 5, it is observed that a field with a strong positive omega is closed over the western half of Iran with 0.2 Pascal/Second (P/S), which indicates air convergence at this level. At the 850 hPa level in Figure 6, the presence of a closed negative omega field with -0.25 P/S over western Iraq and the location of western Iran to the east of this negative omega field indicates severe divergence and increased instabilities on the first day of precipitation. It is observed that over the Mediterranean, the positive omega indicates convergence over this sea. However, over Sudan, along the negative omega field over western Iran, it is completely negative omega, which indicates severe moisture divergence from Sudan to western Iran. At the level of 700 hPa, Figure 7, the negative omega field became stronger and closed at -0.4 P/S over western Iraq, which exactly coincided with the center of low pressure on the earth's surface, and the south-north direction of the negative omega coincided with the location of western Iran in front of the trough.

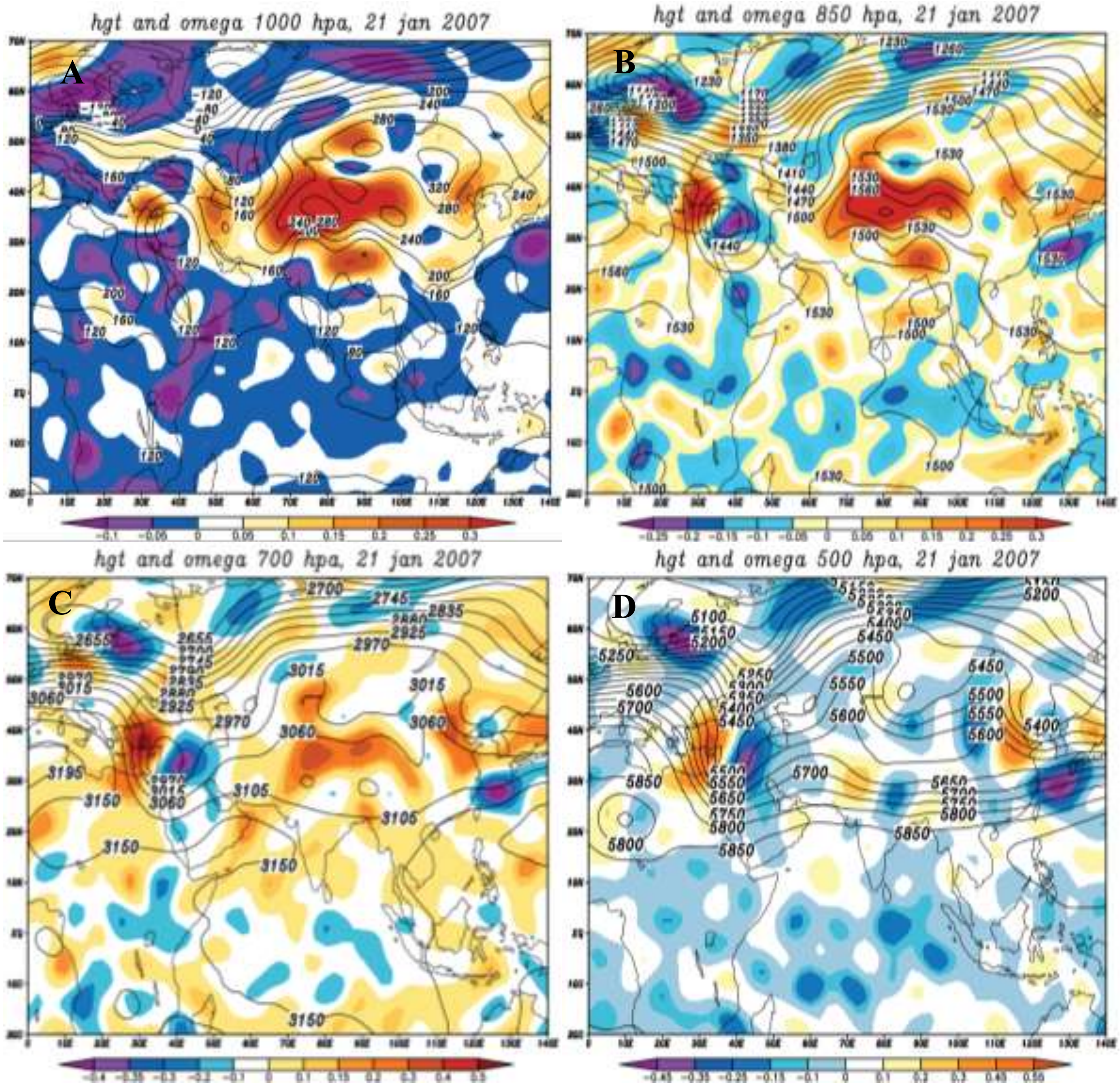

Figure 3. Composite maps of geopotential height (line) and omega (color) on January 21, 2007, one day before the peak of precipitation, at levels A: 1000, B: 850, C: 700, and D: 500 hPa, respectively.

In the 1000 hPa humidity map in Figure 4-A, it is observed that the highest specific humidity with more than 14 g/kg is closed over the Red Sea, which is in the direction of these currents from Sudan, but it reaches less than 12 g/kg over the Mediterranean Sea. It is observed that at the level of 850 hPa in Figure 4-B, the maximum specific humidity is still present over the Red Sea and low latitudes, and the expansion of this specific humidity is located exactly in front of the trough, which is approaching from low latitudes over the western region of Iran. In Figure 4-C, the path of the maximum specific humidity coincides with the east of the trough axis, extending southwest-northeast and passing over the Red Sea, Saudi Arabia and the Persian Gulf, and a second weak moisture core is also in the east of the Mediterranean Sea, which is seen separately in the center of the cyclone circulation. At the 500 hPa level, Figure 4-d shows that the amount and flow of moisture have decreased, but the maximum source of moisture is seen at low latitudes and in southern Arabia and the Gulf of Aden.

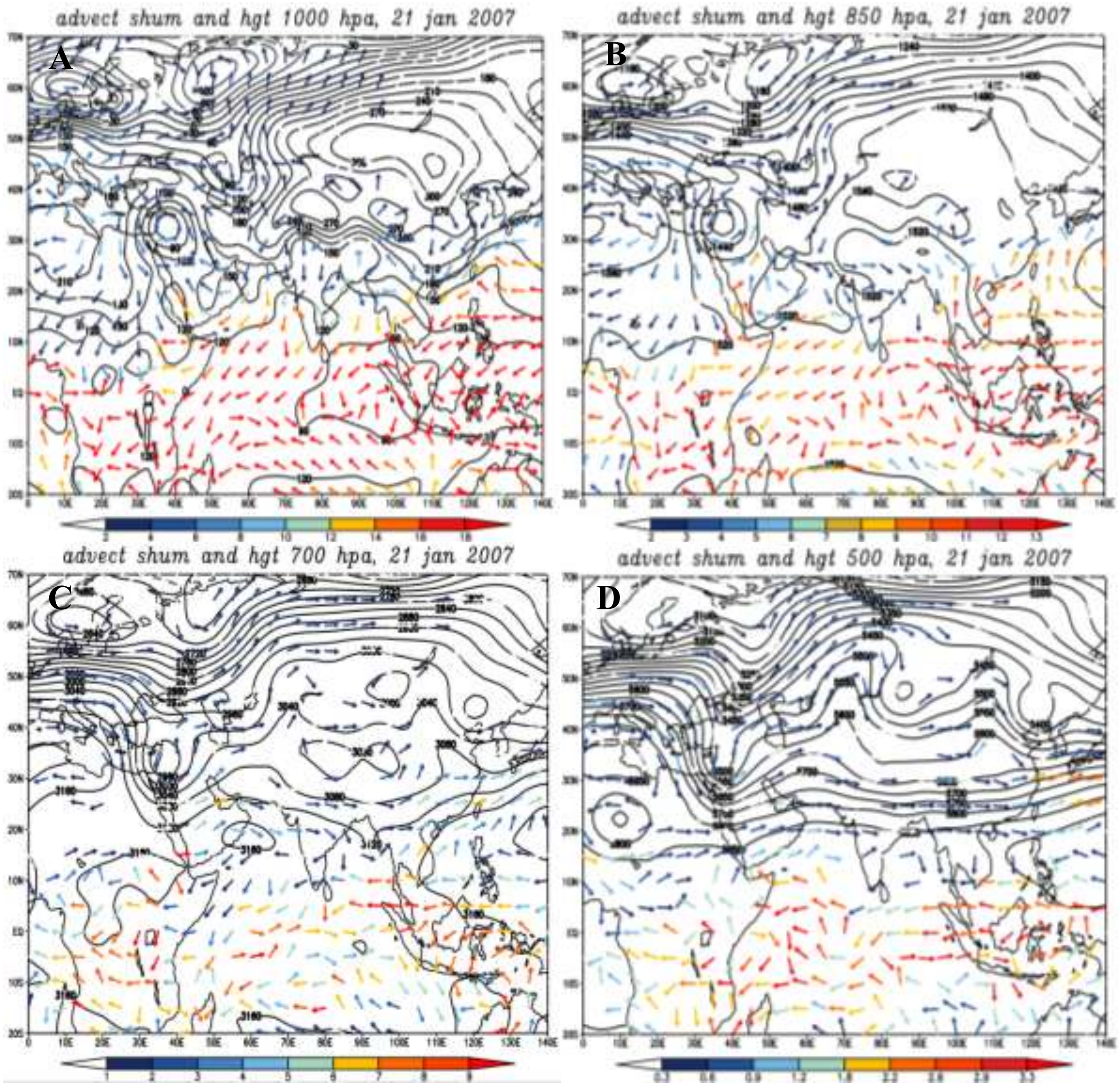

Figure 4. Composite maps of moisture advection (colored arrows) and geopotential height (line) on January 21, 2007, one day before the peak of precipitation, at levels A: 1000, B: 850, 700, and 500 hPa**, respectively**

Figure 5-A shows the 250 hPa level of the jet stream on January 21, 2007, the day before the peak of the precipitation system activity. It can be seen that the core of the jet stream is located in the west-east direction with a speed of more than 60 m/s in southern Iran, Saudi Arabia and the Sea of Oman, with the study area located to the north of the core of the jet stream. In the 300 hPa level of the jet stream in Figure 5-B, while the speed in the core decreases, it maintains its same position at the 250 hPa level, which covers Iran by passing through the northeastern lands of Africa and Saudi Arabia, and at both levels of 250 and 300 hPa, the curvature of the jet stream extends towards the study area and coincides with the path of maximum moisture advection at the east of the trough axis.

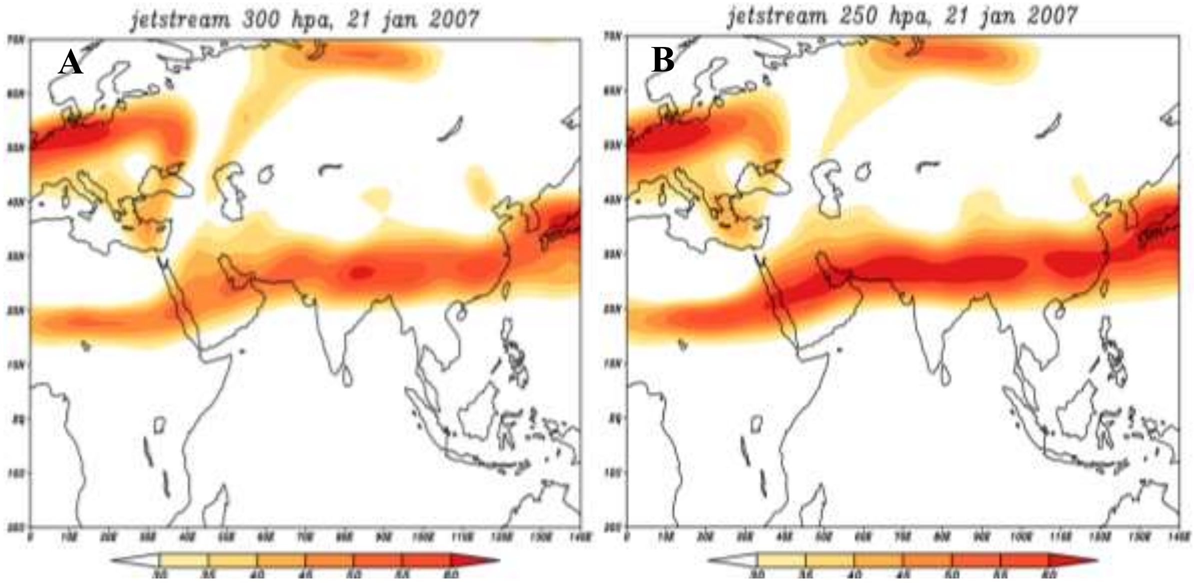

Figure 5. Jet stream maps on January 21, 2007, one day before the peak precipitation at levels A: 300, B: 250 hPa, respectively.

3.2. Synoptic and dynamic conditions on the day of the peak activity of the precipitation system, January 22, 2007

In the sea level pressure map in Figure 6, it can be seen that the low pressure center closed at 1014 in the center of Saudi Arabia and with its south-north extension stretched from southern Saudi Arabia to northwestern Iran. Compared to the closed low pressure the previous day, with an eastward movement from the eastern edge of the Mediterranean to western Iran on the day of the peak of the precipitation, the low pressure center was completely located over the study area. Behind the low pressure system, the infiltration of cold high pressure by passing over the Mediterranean Sea and the advection of warm air from the Arabian Sea in front of the low pressure system increased its intensity.

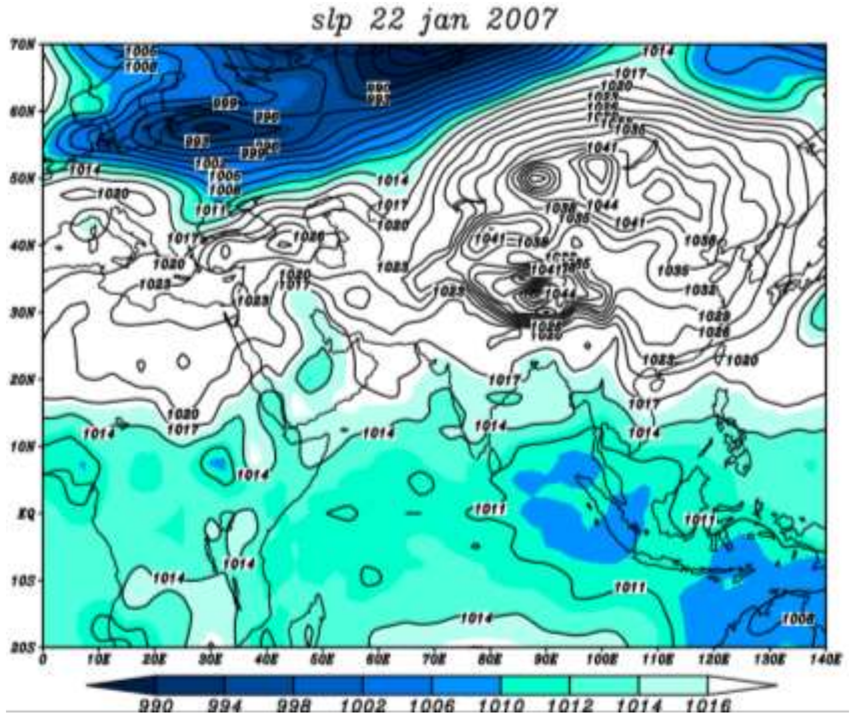

Figure 6. Sea level pressure map on January 22, 2007, the day of peak precipitation (color range: low pressure)

At the level of 850 hPa, Figure 7-b shows the location of the closed cyclone center with 1470 geopotential meters in western Iran, which covers most of Iran and extends from Sudan towards the region with its southwest-northeast curvature, and while deepening and changing the direction of the trough front to southwest-northeast, it has led to an increase in the advection of warm and humid air over the region. At the level of 700 hPa, Figure 7-c, the cyclone center with 3000 geopotential meters has moved eastward, but it has become wider and deeper than the previous day, and its southern tongue has expanded towards low latitudes. With the cyclone center moving eastward, the trough has also moved eastward, and as a result, western Iran has been affected by the instability process of the trough front. And the high over Arabia, while becoming wider, plays the role of feeding more moisture into the Sudanese system. The formation of an omega-shaped blocking in the injection of cold air behind the trough has also led to further strengthening of the 700 hPa trough. It is observed that with the deepening of the trough and the increase in meridional curvature and the eastward movement towards Iran, the warm and humid air has well diverged the southern water resources. In the 500 hPa level map (Figure 7-d), the depth of the trough is greater and the cutoff-low is located over West Asia. In the combined omega-geopotential height map of the 1000 hPa level, Figure 7-a, it is observed that the western half of Iran is dominated by the positive omega field, whose center is closed in northwest Iran with 0.25 P/S, which indicates air convergence in the lower atmosphere. At the 850 hPa level, the center of the negative omega field is closed over the Persian Gulf with -0.2 P/S, which extends to western Iran and indicates the strengthening of air instability and divergence at this level. At the level of 700 hPa, the intensity of the negative omega increased, reaching -0.3 P/S at its center, extending from Sudan to northern Iran with a southwest-northeast curvature, which strengthened the instabilities and showed a peak of precipitation on January 22, 2007.

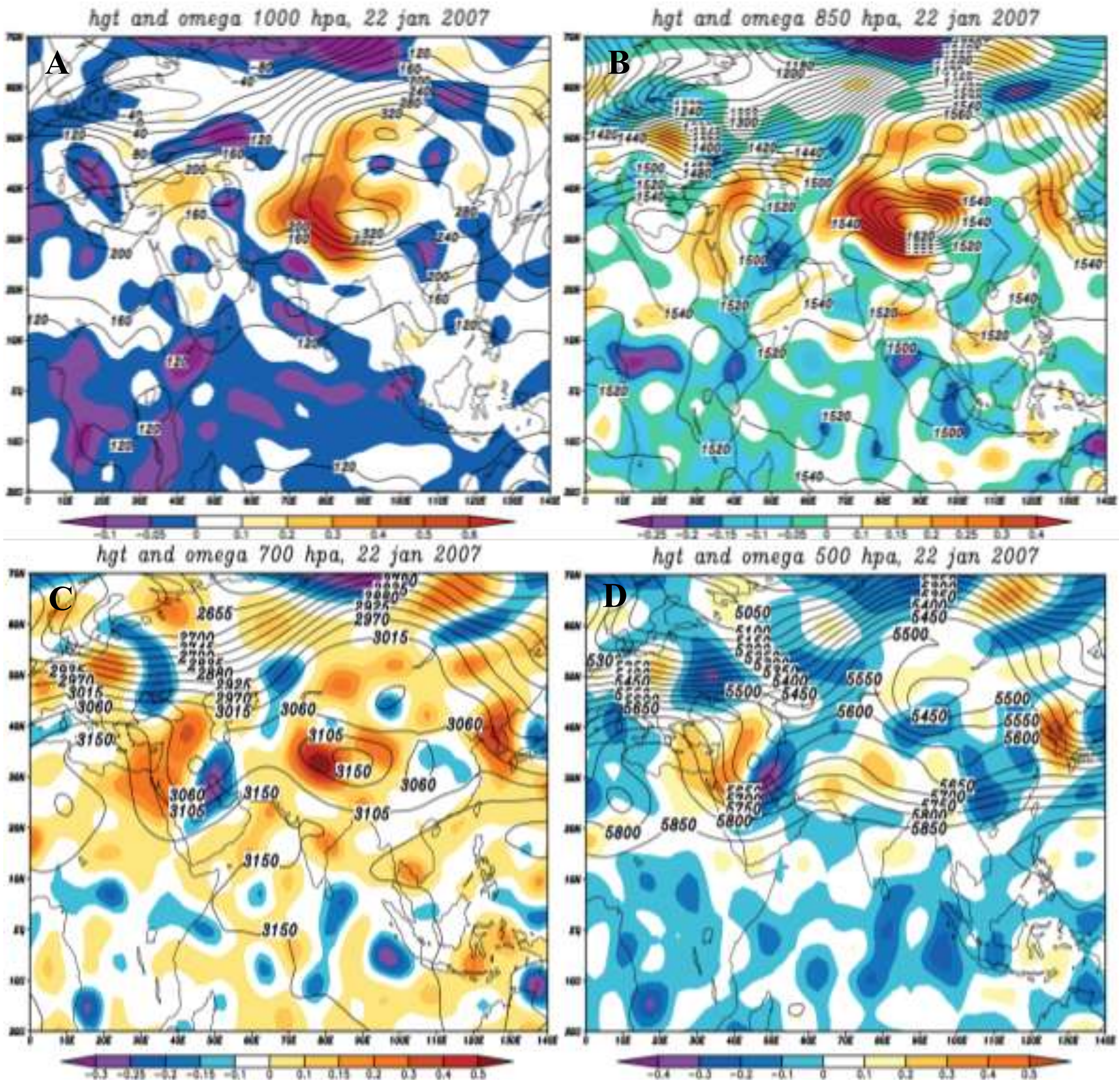

Figure 7. Composite maps of geopotential height (line) and omega (color) on January 22, 2007, peak precipitation at levels A: 1000, B: 850, C: 700 and D: 500 hPa, respectively

In the moisture advection map at the 1000 hPa level, Figure 8-A, a specific moisture core of more than 10 grams per kilogram is observed over southern Arabia, with a counterclockwise wind and a southwest-northeast current direction, which is aligned with the trough map located over the western half of Iran in front of the trough over the study area. At the 850 hPa level, Figure 8-B, the highest specific moisture core is over Sudan and southern Arabia, and the current direction is also in the same direction as the 1000 hPa level and coincides with the trough front, which has caused the advection of warm and humid southern air in the occurrence of instabilities and precipitation in the western half of Iran. The currents over the Indian Ocean are completely westward, and from there, they move towards higher latitudes, passing through the Arabian Sea and advection into the study area. It is observed that the cyclonic circulation, aligned with the Sudanese low-pressure track, with a southwest-northeast direction and passing over Saudi Arabia and the Persian Gulf, has provided precipitation moisture on the peak day. In Figures 8c-d, the levels of 700 and 500 hPa also have the maximum specific humidity in the south of the Red Sea and Arabia, but compared to the lower levels of the atmosphere, the path of moisture entry has shifted to the east and has advected from the southeast of Arabia and the west of the Arabian Sea, passing over the Persian Gulf and with a deep cyclonic circulation coinciding with the east of the trough axis, advection over the western and southwestern regions of Iran. It is observed that at the levels of 700 and 500 hPa, the strengthening of the anticyclonic circulation over the Arabian Sea plays a major role in sending moisture into the Sudanese low-pressure system and in front of the trough.

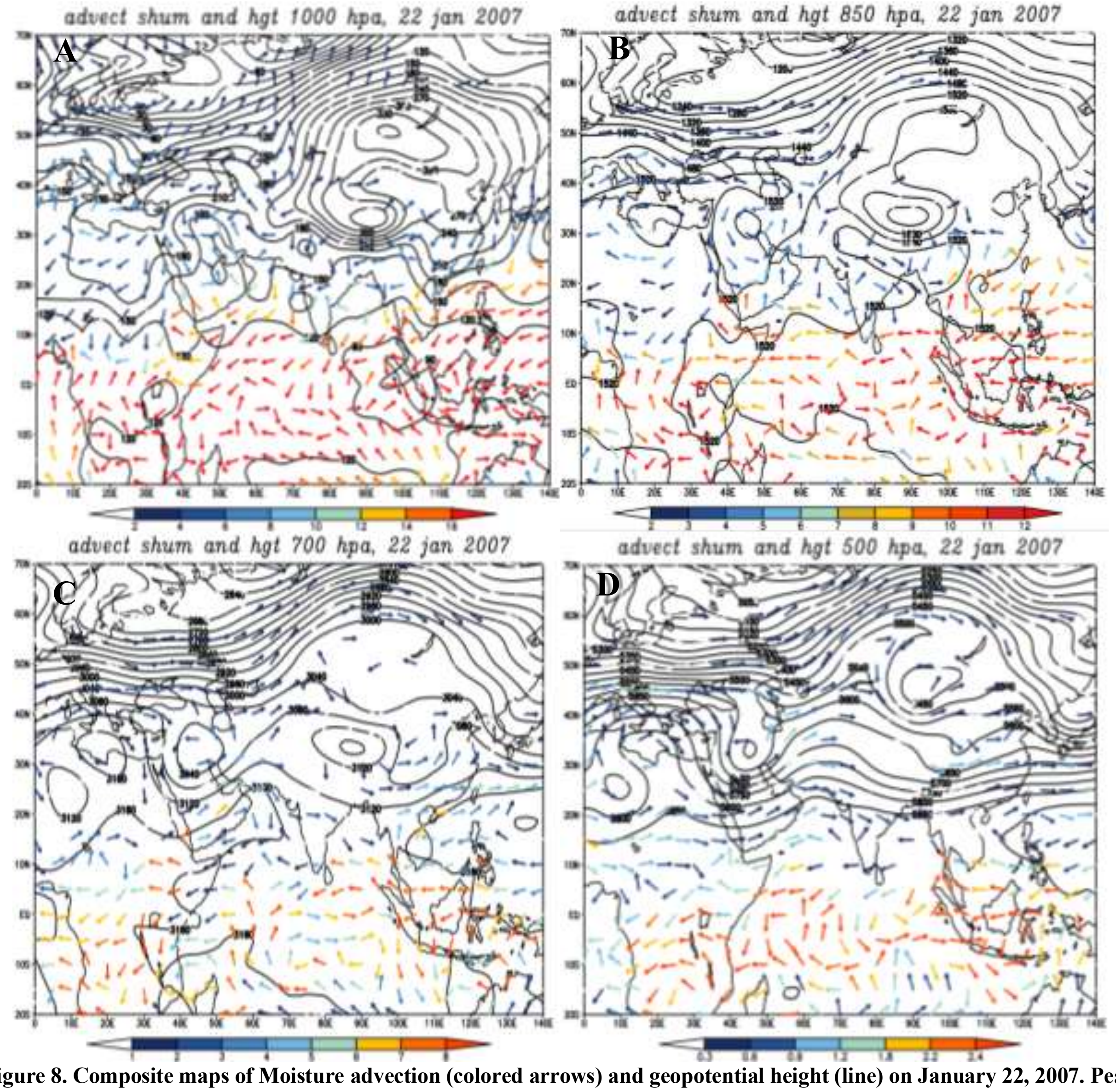

Figure 8. Composite maps of Moisture advection (colored arrows) and geopotential height (line) on January 22, 2007. Peak precipitation , at levels A: 1000, B: 850, 700, and 500 hPa, respectively.

Figure 9 shows the total specific humidity map of 1000 to 500 hPa levels during rainy days in western and southwestern Iran. Based on this map, it is observed that the cores of maximum specific humidity in East Africa and the low pressure area of Sudan with an intensity of more than 80 g/kg have been formed, which indicates the effect of east-west circulations from water resources towards land, from where, due to the penetration of the mid-level atmospheric trough to these areas, conditions have been prepared for the advection of specific humidity with a southwest-northeast extension towards the study area. Here, by eliminating values less than 35 g/kg, the specific humidity path has been more clearly identified.

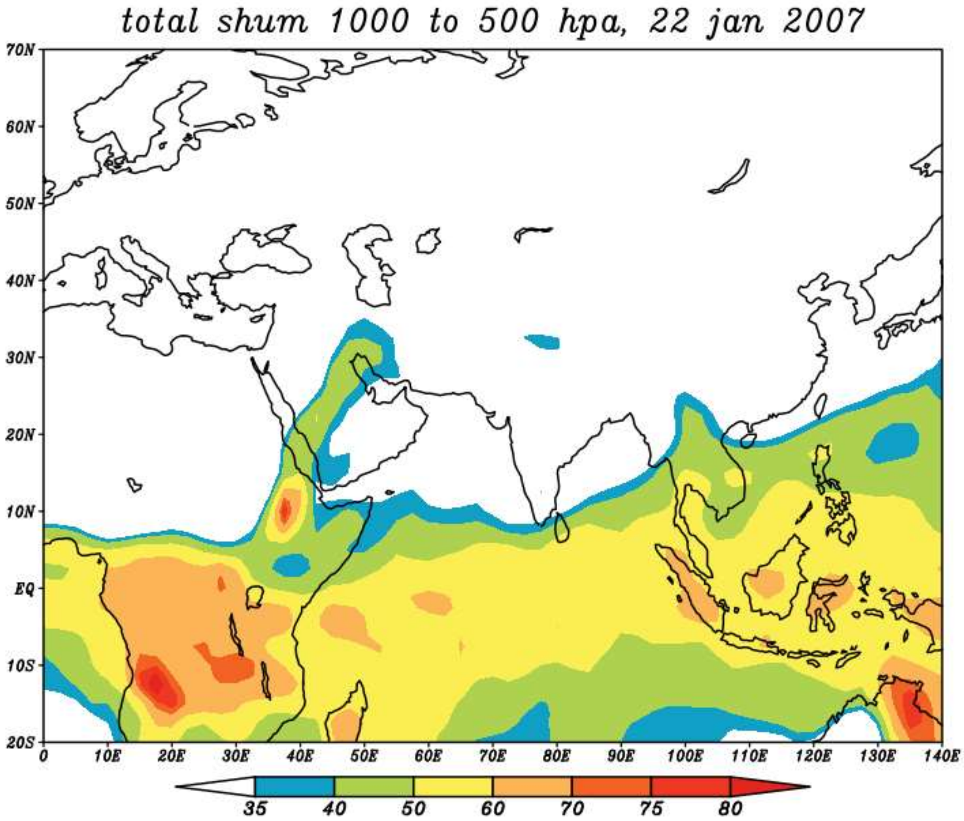

Figure 9. Map of total specific humidity for the rainy days of January 21 and 22, 2007

Figure 10 shows the jet stream at levels of 250 and 300 hPa on January 22, 2007. On the day of the peak rainfall, the subtropical jet stream, entering from the northeast of Africa and located on the left side of the jet stream outlet over the western half of Iran, shows the highest divergence. The central core speed is very high at levels of 250 and 300 hPa, 60 and 55 meters per second, respectively. By passing over the southern sources and lands in a southwest-northeast direction, and the jet stream coincides with the upper divergence and east of the trough axis, and coincides with the specific moisture path and vorticity maps, it has provided cyclone-forming conditions in the region and led to an intensification of instabilities.

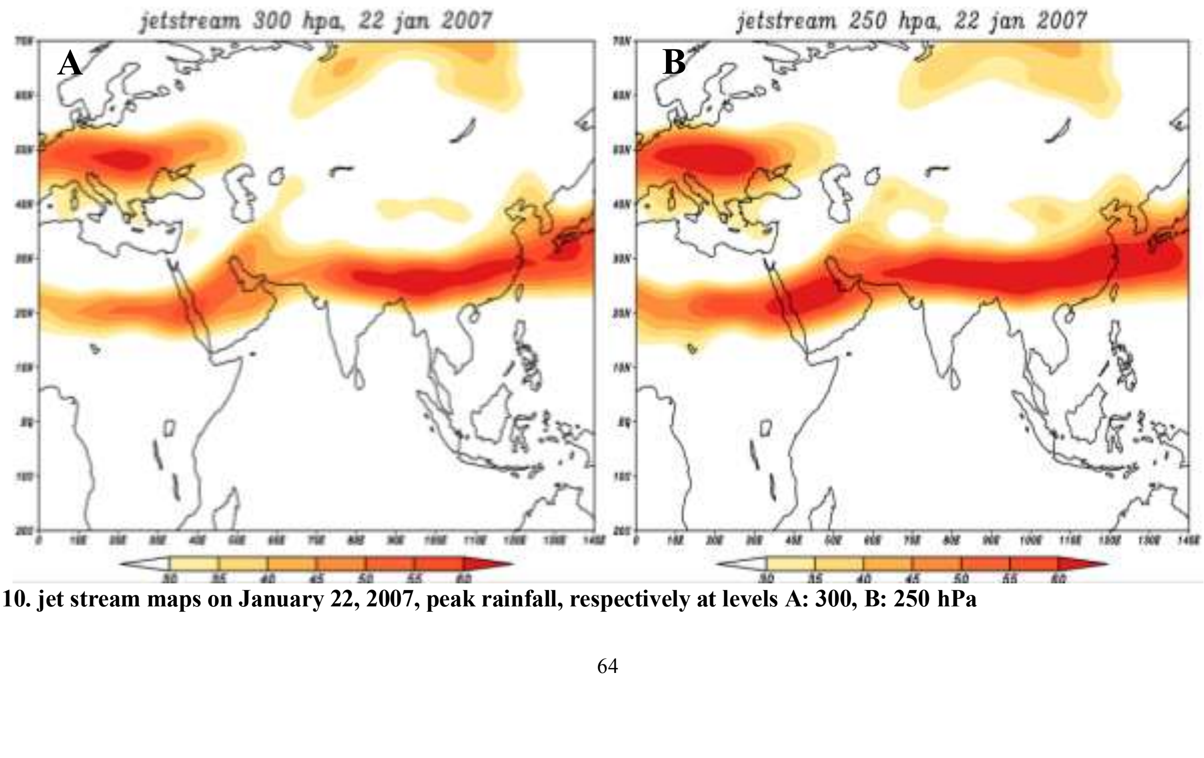

Figure 10. jet stream maps on January 22, 2007, peak rainfall, respectively at levels A: 300, B: 250 hPa

4. Conclusion

The occurrence of widespread and heavy rainfall in the west and southwest is a prominent characteristic of these regions. Since the moisture factor is more important than the ascent factor for creating widespread and heavy rainfall, it seems necessary to identify the sources and origin of precipitation moisture. In this study, the synoptic and dynamic conditions of the heavy and widespread rainfall on 1 and 2 Bahman 1385, corresponding to 21 and 22 January 2007, and its relationship with the moisture sources adjacent to Iran and the Sudanese and Mediterranean low-pressure systems were investigated. In the sea level pressure maps on the first day of precipitation, the Sudanese and Mediterranean low pressure systems merged on the eastern edge of the Mediterranean and on the day of peak precipitation, the center of the Sudanese low pressure system was independently closed over western Iran and high pressure centers were located in northwest Iran and over Turkey with 1032 and 1028 hPa, whose northwest-southeast lobes introduced cold air behind the Sudanese low pressure system, increasing the thermal gradient and strengthening the Sudanese system on the day of widespread precipitation in west and southwest Iran. Examination of the omega and geopotantial height maps also indicates divergence and severe cyclonic rotation in the ascend of moist air on the day of precipitation. With the deepening of the trough over Arabia and Iraq to the Red Sea region and its association with the Sudanese low pressure on the surface of the earth and its movement in the southwest-northeast direction over the study area and the Arabian high pressure with its establishment over the Arabian Sea and Oman is the main factor in transferring the moisture of the Arabian Sea and Oman into the Sudanese low pressure. The high pressure established over the Arabian Peninsula, the Arabian Sea and the northwestern Indian Ocean as one of the necessary conditions for the formation, strengthening and development of the Sudanese low pressure (Lashkari, 2003, 134) helps to further strengthen the precipitation system by advection of warm and humid air into the precipitation system. In the troposphere maps on the day of the peak activity of the precipitation system, the western and southwestern regions, which had a positive troposphere maximum, faced widespread and heavy rainfall. Jet stream maps at the levels of 250 and 300 hPa indicate the location of the subtropical wind with a southwest-northeast direction that passed through the northeast of Africa and the core of the maximum jet stream speed was over Arabia and the Red Sea. The studied area was also on the left side of the jet stream outlet, which coincided with the omega path and humidity and the left half of the jet stream outlet was located exactly in the east and in front of the trough axis, which has well discharged and diverged the ascending air in front of the trough. The results of this study on the impact of the Sudanese system are consistent with the research of Lashkari (1996), Mofidi (2004), and Omidvar (2007). Also, the largest amount of moisture was taken from the water sources of the southern Red Sea, western Arabia and Oman, respectively, while there was a small amount of moisture transfer from the Mediterranean. Which is consistent with the results of Darand and Pazhoh (2019).

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