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Summer precipitation determinant factors of Iran's South-East

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Abstract
Indian Ocean is known as a source of moisture for southeast of Iran due to summer precipitation. In this study, in order to investigate the role of SST of Indian Ocean, and the convergence and divergence fields in the precipitation of southeast of Iran, precipitation data of five synoptic stations were used during 2000-2010, including Iranshahr, Khash, ChahBahar, Zabul, and Saravan. To investigate synoptic circumstances of precipitation, different atmospheric levels of data was obtained from National Oceanic and Atmospheric of United States (NOAA) website with the horizontal resolution of 5.2 degree. Afterward, maps of wind, heights, and moisture flux were prepared. The results show that these three important factors (including Indian Ocean surface temperature (SST), convergence and divergence fields, and monsoon returned east jet stream) have one important role in the summer rainfall event for the study region. In addition, summer precipitation is influenced by the wet and shallow summer monsoon, sea surface temperatures, and convergence and divergence in continental regions. East jet stream have also been effective in these regions. Summer rainfall patterns have played roles in this region, including the convergence of the wind in southeast of Iran and the divergence of wind in the southeast of Arabian Peninsula in first pattern. The above circumstances as well as high temperatures of sea surface are considered in second pattern, and high sea surface temperature and the monsoon East jet stream in third pattern.

Keywords
convergence, divergence, geo-potential height, sea surface temperature, the upper divergence.

1. Introduction
Climate is one of the complex physical, chemical and biological interaction associated with the atmosphere, ocean, land, snow, sun, and tectonic topics. Since oceans and seas cover more than 70% of the Earth's surface, it can imply their important role in climate change and variation due to immense capacity of oceans to store and distribution of heat. It is clear that the effect of water surface temperature on precipitation is not limited to coastal areas, but also areas far from the sea can affect (Nazemosadat & Ghasemi, 2004). By the 1980s, sea surface temperatures (SST) patterns were only considered as one of the results of atmospheric circulation processes affecting the precipitation of coastal areas. But at the moment these changes are considered as factors that their effects on the precipitation of coastal areas are more than the impact of the atmospheric circulation (Hulme et al., 1993).

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Sea Sand Ocean's surface temperature is considered as an effective controlling factor in global climate. In recent years, study of the ocean-atmosphere interaction and its impact on arid areas bordering oceans attracts scientist attention that we refer to some cases here. Examining of SST characteristics and medium-term and long-term changes in West Pacific, Atlantic and Indian Oceans, which were done by using correlation and spectral analysis indicates sudden changes in the ocean surface temperature (Zhang et al., 2001; Hung & Hung, 2009). Study of SST effects and its anomalies on tropical areas showed that sea surface temperature can reduce the velocity and frequency of waves. In addition to this, SST anomaly caused instability in waves in a long period of time (He Jinhai et al., 2007).

The results of precipitation forecast in the Indian Ocean using sea surface temperature (Bollasina & Nigam, 2009), as well as the role of the above processes in weather forecasting systems (Jasti et al., 2015) showed that ENSO phenomenon during the warm phase has caused more precipitation occurrence in connection with the justification of sea surface temperature that this interaction has occurred in the ocean-atmosphere system. The analysis of the fourth IPCC report on sea surface temperature and its evaporation in the Indian Ocean showed that about 50% of summer precipitation in North India is the result of the ocean-atmosphere interaction of the atmosphere that some variations in Indian Ocean surface temperature have been observed in recent decades. Observing Indian Ocean surface temperature during the period of 2008-1950 using empirical orthogonal functions and correlation analysis revealed that the occurrence of El Niño and Southern Oscillation (ENSO) and global warming on the Arctic Ocean, a uni-polar model on the ocean is evident that it caused the lack of climate diversity on the ocean (Dietmar, 2011; Rao & Rongcai, 2015). The relation of the remote bond patterns and the Indian Ocean SST showed that a two-year track between ENSO, ISM, IOD systems has been existed positively that Followed by global warming (Ghyslaine et al., 2012). Indian Ocean SST effects on monsoon, using simulation model, indicates that the sensitivity of the monsoon to SST performance has varied in two hot and cold phases, which consequently was followed with caused change in winds during two phases (Chloe et al., 2014).

Sea surface temperature (SST) analysis in tropical areas showed that there is a great correlation between SST and precipitation, which has caused spatial variability in precipitation and SST of mentioned areas. However, some limitations existed, like an error in the prediction model (Ming yue et al., 2015). The Western Pacific precipitation associated with SST, ENSO and moisture flux convergence showed a high correlation between moisture of the ocean surface temperature with precipitation in these areas that these precipitations had been evident more in western parts of the tropical Pacific Ocean (Byeong & Kyung, 2015). Decades and middle-age diversity analysis in the Indian Ocean surface temperatures indicates that the Indian Ocean has been in a specific Dipole Mode (IOD) and it is in middle-age form between SST and IOD that is the simulation mode of two phases of ENSO (Krishnamurthy & Krishnamurthy, 2015). The existence of changes in precipitation between decades in the South China with the Indian and Pacific monsoons is also evidenced (Renguang et al., 2012).

A study that was conducted on the Indian Ocean surface temperature range showed that the high rate of SST was in spring, which was associated with monsoon-summer in these areas. These results are based on a regression mathematical model using the mean wind speed and obtained solar radiation (Shenoi et al., 2009). During the winter, the effect of Mediterranean Sea surface temperature fluctuations on rainfall in the western of Iran revealed that when Med SST is colder than usual, the winter precipitation increases in the study area. But when temperature is warmer than usual, autumn precipitation is increased (Jahanbakhsh Asl et al., 2012; Rezaei et al., 2010).

The impact of Oman SST anomalies on autumn and winter precipitation in the southeastern coast of Iran is considered as the main mechanism for changing in the rainfall of this area. In this precipitation conditions, flow lines pass a longer route across the sea and their amount of moisture absorption increases and provide better conditions to create precipitation (Khosravi et al., 2011). Changes in sea surface temperature in the Persian Gulf significantly affect rainfall fluctuations in the wide range of southwestern and southern Iran (Nazemosadat, 1998).

This paper examines the SST, wind convergence at ground level and divergence in the middle levels of troposphere. The convergence takes place in certain atmospheric conditions in which air flow lines meet each other and the air accumulation in the upper region of atmosphere occurs. The specific circumstances in which the air flow lines move in opposite directions is called divergence. Divergence occurs when levels of the upper atmosphere allows the air to rise and cause precipitation. Therefore the aim of this study is to determine the three important parameters (Indian Ocean SST, the wind convergence, and divergence fields at Geopotential level) of rainfall in the southeast of Iran. Southeastern region of Iran has less rainfall than other regions due to its geographical location and remoteness of Mediterranean water sources. So, study of synoptic conditions and mechanisms that cause summer precipitation in these areas is very important.

2. Study area

The southeast part of the country is located in dry climate part of the world in which the amount of annual rainfall proportion is much less than the amount of annual evaporation. The area under study (Sistan-va-Balouchestan) is between eastern longitude of 57-64 and northern latitude of 25-35 (Fig. 1). The height of the area is between 8 to 489.2 m. Rainfall in this area is not only very low, but also irregular. In addition, as result of high temperature, the area is dry, and vegetation is also poor. A main characteristic of the area is the stability of temperature over the years. The annual period is divided into two periods of cool and warm. The cool period contains December, January, and February. Frosty days in this area are negligible. From mountainous point of view, this area has low-height mountains that is an evidence of dryness of this area from climatology view.

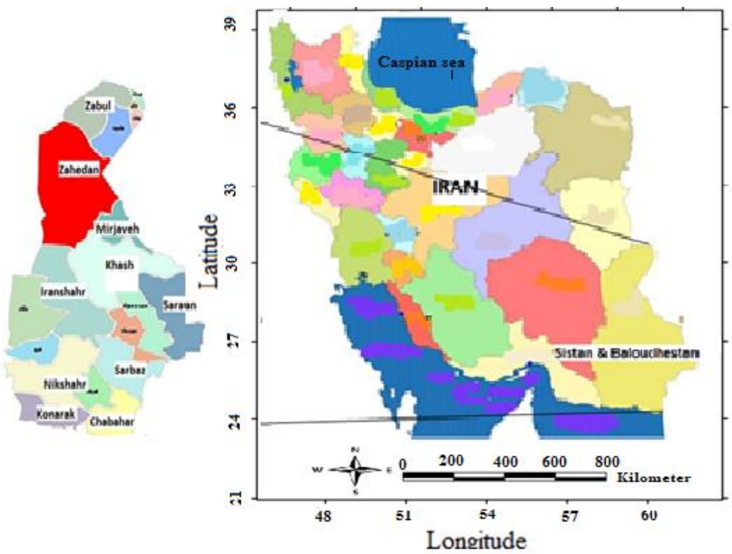


Fig. 1. Map of the geographical location of southeast region and selected stations in Iran

3. Materials and Methods

In order to investigate the subject of this study, a circulating approach was used. First, daily precipitation data of five selected stations of the southeast of Iran (Khash, NikShahr, Chabahar, and Zabol and Saravan) was obtained from Meteorological Organization (indices of selecting stations, occurrence of precipitation at 60 percent of the stations has been studied) during 2000-2010. Figure 1 shows the location of case study.

In the following, daily data of anomaly sea surface temperature (ASST), sea surface pressure (SLP), zonal and meridional wind components, geopotential height, and relative humidity of 700 hpa level in location of Indian Ocean (80-50 degrees east longitude and 10-35 degrees north latitude) were selected for selected patterns through NCEP atmospheric database affiliate to the United States Oceanic and atmospheric National organization (downloaded from www.esrl.noaa.gov/psd). Then, the interpolative and combinatorial maps of wind and SST anomalies, geopotential height, and water wind were drawn by using Grads software for selected patterns (representative days).

4. Results and Discussion

Flows over the Indian Ocean are affected by monsoon low pressures that it, consequently, intensifies a convergence center on Ganges Valley. Consequently, these flows over the Arabian Sea come in southwest flows. These southwest flows with their counter-clockwise movement bring moisture into the southeastern, and adjunct areas to the coast and the summer monsoon precipitation conditions and severe storms of warm season in the area. Local thermal convections is also effective in rising increase and ultimately condensation and precipitation of moist air masses (Saligheh, 2006: 12).

4.1. The first model: Convergence and divergence in geopotential levels (06/12/2005)

Figure 2 shows the Distribution of annual precipitation (mm) in the study area on 6/12/2005. According to Figure 2, dark colors show high precipitation and light colors show low precipitation. The eastern regions of the province have more precipitation. Also the most part of the area under study has a rainfall below 1 mm.

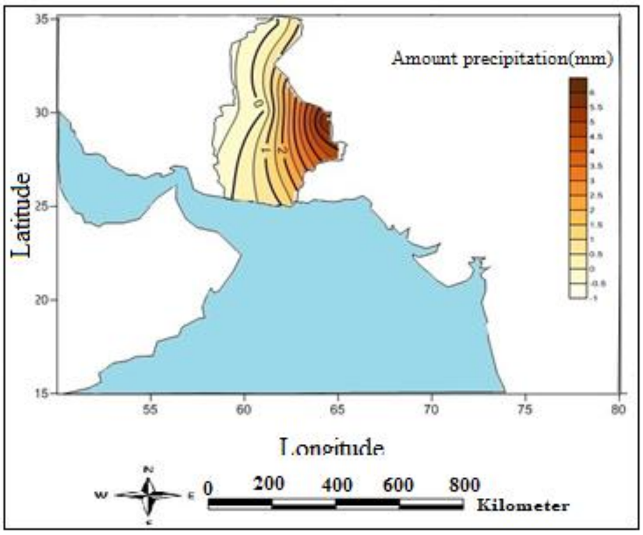


Fig. 2. The distribution of annual precipitation (mm) in the study area on 12/06/2005. Eastern regions have more precipitation.

4.1.1. Climatic characteristics sea surface

Figure 3 shows the distribution of Indian Ocean surface temperature, wind currents and convergence and divergence fields in the vicinity of Earth surface. The produced moisture from the Indian Ocean and Arabian Sea is carrying by these wind currents to the northern coast of Oman. In the South East of the Arabian Peninsula, on a narrow strip of the northeast to the southwest, the divergence of air makes wind currents. This wind flows with the northeast direction passes across the warm waters of the Indian Ocean and Arabian Sea and, after absorbing abundant water vapor, it affected by convergence zone formed in the southern land of Iran. Then, it rotates to the inner region of Sistan and Baluchestan, and extends its moisture to inner regions of Iran. It is the primary factor of driving moisture wind currents towards these regions such as the north of Persian Gulf, the Strait of Hormuz in a large line, and Sistan regions a lower convergence zone. General currents of the region are cause by a divergence field and two convergence fields that one caused by dynamic factors (divergence field of the Arabian Peninsula), and the other caused by thermal factors (the Northern convergence field of Oman Sea, the Strait of Hormuz and the Persian Gulf, and the convergence field of the large Sistan Plain). Convergence fields formed on the Iran plateau can be created due to a relatively transparent atmosphere, intense solar radiation and high sunshine hours, in this period of the year.

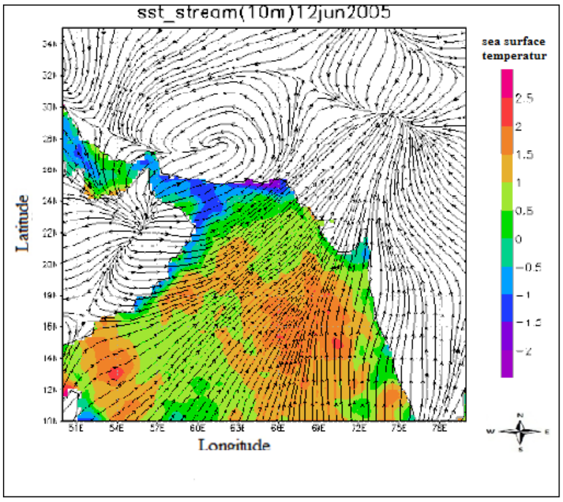


Fig. 3. The formation of the divergence field in the southeast of the Arabian Peninsula and the formation of the convergence field on the large Sistan Plain, and the northern edge of the Strait of Hormuz and the Persian Gulf on 06/12/2005, wind flows over the Indian Ocean and Arabian Sea are like the southwest monsoon.

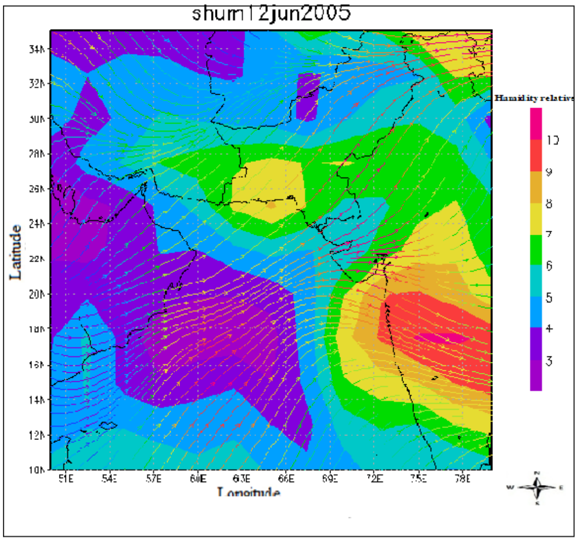


Fig. 4. It shows the distribution of humidity fields and wind flow in 700 hpa On 06/12/2005. The high moisture core has been formed on the southern coast of Pakistan and its tabs has reached from the west to north of the Strait of Hormuz. The high moisture core is spreading to the east due to the emergence of wind convergence fields in the north coast of Iran.

Figure 4 shows the distribution of moisture fields and wind currents in 700 hpa, known as the most important balance of the moisture transfer. Wind flows in this balance are the southwest flows that flow out their humidity of the Indian Ocean and adjacent seas within the study area. High moisture core from this atmospheric flow has been formed in the southern coast of Pakistan and its effects have reached from the west to the north of the Strait of Hormuz. It has been predefined that this high moisture core will be spreading to the east due to the emergence of wind convergence fields. one of rainy stations in these days shows the high humidity curve of 8 kg dry air has reached the south-eastern borders of Iran and the region of Saravan,.

4.1.2. 500 hpa level

Figure 5 shows the wind flow map and distribution of geopotential height at 500 hpa. According to the map, a deep trough axis Northeast controls the Southwest atmospheric flows of this balance. Conditions suggest that a small part of the South East region of Iran is located in the high divergence region in the East axis of this trough. A weak divergence field in this balance help slows convergence fields in rising and air density. But in other northern areas of the Oman Sea and Persian Gulf, the divergence field of the mid-troposphere level is not strong enough to repeat this role. That's why in these areas, there are the lack of rainfall or minimal precipitation. The formation of a bipolar system in the West Indian subcontinent caused the formation of a barrier system followed by the reduction in the speed of wind flows. The above bipolar system plays an important role in the bifurcation of wind flows in this level and intensifies the divergence.

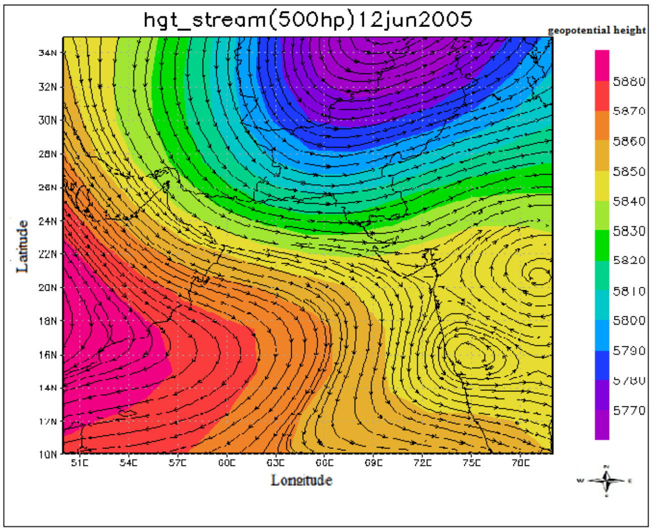


Fig. 5. It shows the map of wind flow and distribution of geopotential height at 500 hpa on 12/06/2005, a small part of the Southeast region of Iran in the upper divergence field helps the lower convergence field in rising and air density. A west bipolar system in the Indian subcontinent formed the barrier system and reduction in speed of wind flows.

4.2. The second model: the effect of sea surface temperature and convergence and divergence geopotential levels (26th and 27th of June 2007)

Figure 6 shows the distribution of total daily rainfall in 26th and 27th of June 2007. The dark colors show high precipitation and light colors show low precipitation. The eastern part of the study area has the highest precipitation (mm), the role of sea surface temperatures in transferring the moisture to the mentioned areas is investigated as the most important factor in this precipitation.

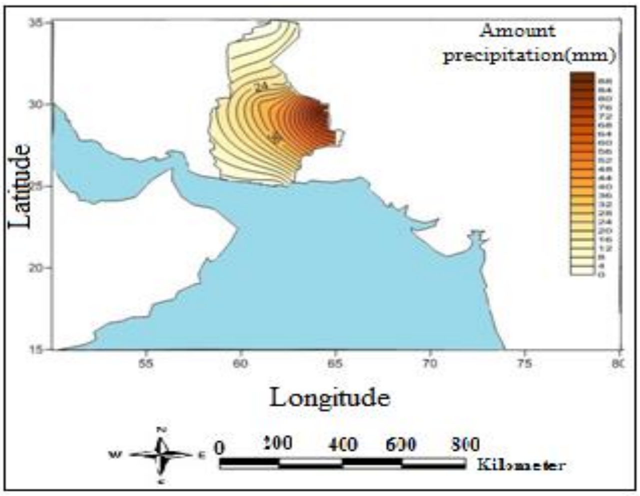


Fig. 6. The distribution of total daily precipitation (mm) of selected stations in 26th and 27th of June 2007. The center of gravity precipitation of the eastern and central regions has been studied.

4.2.1. Sea surface

Figure 7 shows a combination of the Indian Ocean temperature anomaly circumstances and wind flow fields (convergence and divergence) on the Earth surface. According to this figure, small-scale convergence zone in northwestern parts of Pakistan and a large scale in the southern half of Iran along with Western Europe can be seen. According to Figure 6, the highest precipitation in parts of eastern and central provinces is the evidence of this issue. In this model, the average temperature of the Indian Ocean is two degrees above the average. The high temperature is a factor that plays an important role in providing moisture. So, the convergence and divergence fields, rising air and the positive anomaly of the Indian Ocean surface temperature provide the moisture.

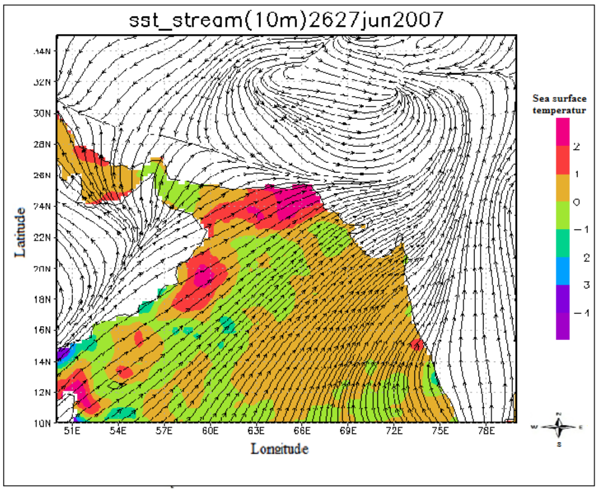


Fig. 7. Wind flow and sea surface temperature map in 26th and 27th of June 2007. The convergence and divergence fields and sea surface temperature have the most important role in the two-day precipitation.

Figure 8 shows the spatial distribution of moisture flow. It is the moisture source for the Indian Ocean precipitation in 26th and 27th of June 2007. There are some positive anomalies in the Indian Ocean surface temperatures that provide conditions for necessary humidity for precipitation in this time of the year in southeastern areas of Iran. Water flows after passing over the ocean and getting enough moisture by taking the path on the northern coast of the Arabian Sea and Persian Gulf enter the southern East of Iran. High humidity curve in the southeast is 8 to 12 kg, which marks the entry of high humidity to these areas.

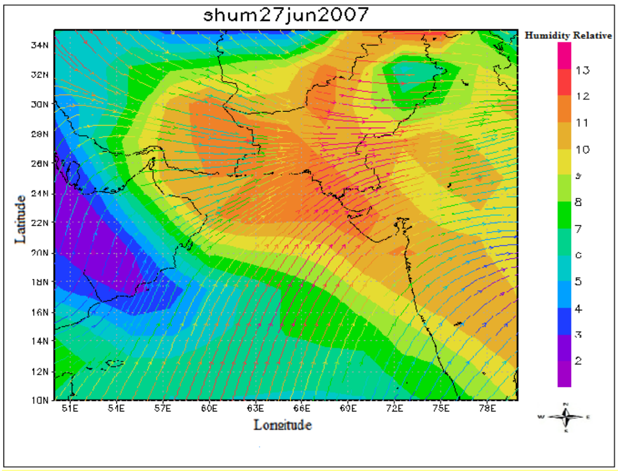


Fig. 8. The distribution of moisture and wind currents in 700 hpa on 27/6/2007, formed the high moisture nucleus on Pakistan and parts of South East of Iran through the entered moisture from the Indian Ocean which caused a notable rainfall event in these areas.

4.2.2. 500 hpa level

Figure 9 shows the wind flow and distribution of the geo-potential height at 500 hpa level in 26th and 27th of June, 2007. According to this figure, in the southern part of India, a closed low height center has been formed with a deep planetary motion. This low height center plays an effective role in the formation and development of convergence zone, which means that as the convergence zone forms in this level. The dynamic factors add to thermal factors in lower levels and reinforce the sea surface convergence field. In north of Pakistan, east of Afghanistan and, the central region of Iran, the elevated centers by anti-cyclonic movements increased the pressure gradient. Proximity of these two cores leads to the alignment of air flows from east to west, and a mid-divergence region is formed on the Arabian Sea. The low planetary motion and its alignment with the North Streams are the most important factors needed for transferring moisture and creating required rising conditions for precipitation in this period.

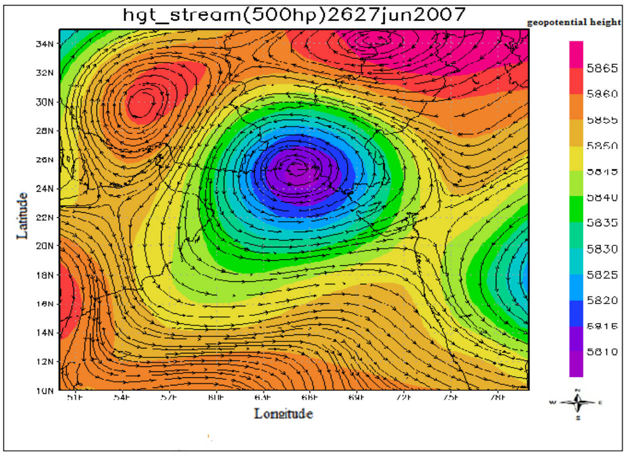


Fig. 9. Map of wind flow and distribution of geopotential height at 500 hpa on 26th and 27th of June, 2007. The presence of Ganges' low pressure core causes Indian Ocean moisture with clockwise rotation to enter in the southeast of Iran, and the occurrence of precipitation.

4.3. The third pattern: the impact of sea surface temperatures and eastern jet stream (4th, 5th and 6th August, 2008)

Figure 10 shows the distribution of total daily precipitation on 4th, 5th and 6th August, 2008. The dark colors show high precipitation and light colors show low precipitation. It had the most precipitation (mm) in west part of the province. The main precipitation basin is located on the Jazmurian basin. The precipitation of this time of the year is highest in western parts, which is above 11 mm.

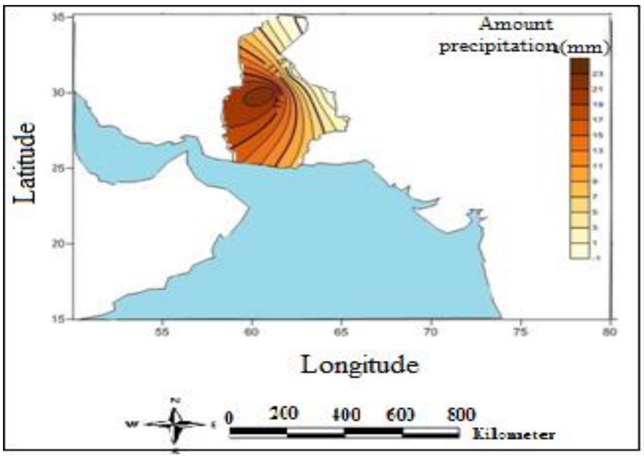


Fig. 10. Distribution of total daily precipitation (mm) of the studied region on 4th, 5th and 6th August, 2008. The most precipitation occurred in the western region and Jazmurian basin.

4.3.1. Surface of the Earth

Figure 11 shows the distribution of sea surface temperature, and wind convergence and divergence fields. In the studied pattern, sea surface temperature played an important role in the formation of precipitation in southeast of Iran. So that the surface temperature of the Indian Ocean was between 1 and 2 Celsius degrees higher than the long-term average on the same date. For the most parts, temperature was between -1 and 1, which shows cold sea temperature at this time of the year (May). But, on the margins of the Arabian Sea and southeastern parts of Iran, the most precipitation was in May, due to high sea surface temperature (SST). While, a weak convergence field, which is not effective, can be seen in southeastern areas due to the high sea surface temperature.

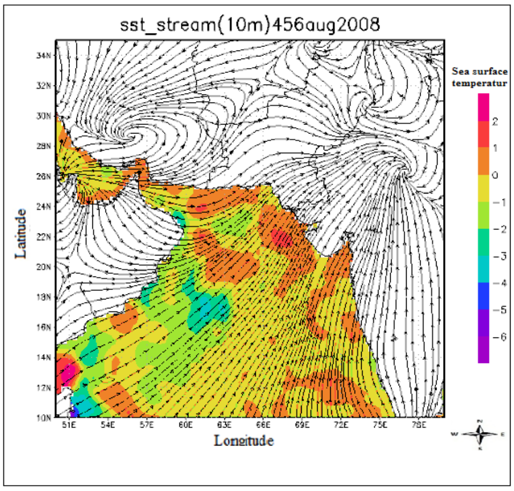


Fig. 11. A map of wind currents and sea surface temperature anomaly on 4th, 5th and 6th August, 2008. In the studied pattern, sea surface temperature played an important role in the formation of precipitation in southeastern regions.

The distribution of moisture fields showed (Fig. 12) that in the southeastern parts of Iran they exit so densely and enter the eastern borders of Afghanistan and Pakistan, when water flows are passing through the Persian Gulf and Oman Sea. Water flows in the southern parts show winds pass a long path, and absorb more moisture from the Indian Ocean. So that the moisture cores have been observed with 7 to 8 kg curves over the Indian Ocean. But, the interesting point is the presence of the moisture core on Pakistan, which is related to shallow and wet streams of summer monsoon.

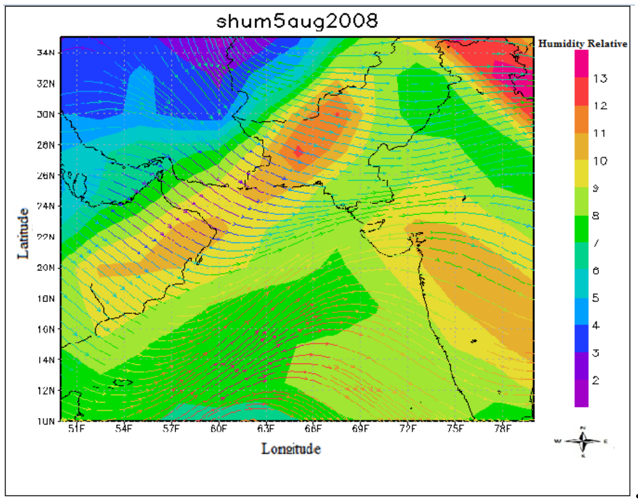
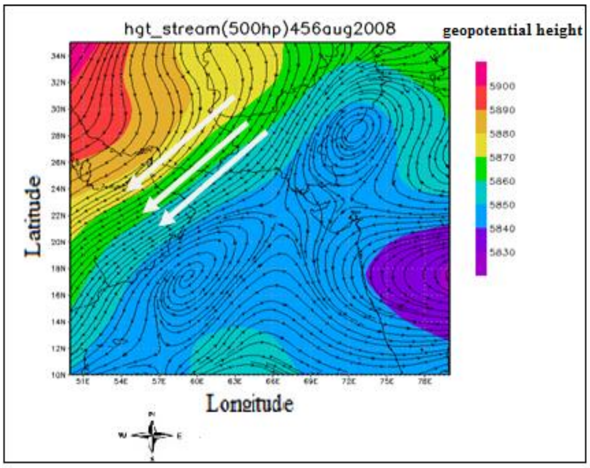


Fig. 12. The distribution of humidity and wind flows in 700 hpa on 05/08/2008. It shows the presence of high moisture core on Pakistan, which is related to shallow and wet streams of summer monsoon.

4.3.2. 500 hpa Level

Figure 13 shows the characteristics of the 500 hpa atmospheric flows. In northern and north eastern parts of the Indian Ocean, divergence conditions increase the level of positive vorticity field and precipitation occurs. Wind flows in this level, and lower levels pass a long distance across the Indian Ocean, and move toward west and northwest of the ocean, then enter Iran from the southeastern parts. In this pattern, with regard to the figure 13, wind flow lines can be seen so densely in southeastern areas of Iran, which is a sign of a low pressure backflow monsoon, which is known as the eastern jet stream. It is shown in the figure as lines close to each other. Thus, earth surface thermal changes control the influence of the eastern jet stream in this level and the role of general circulation, on a large scale, in winds direction is vanished. The surface trough center can also be seen to this level. At this time of the year on the Earth's surface, monsoon thermal trough forms that its secondary center stretches to the southern part of Iran due to the received energy. Increasing the congestion of wind current lines in the mentioned figure on the southeast of Iran demonstrates the increase of the wind flow speed and the formation of the east jet stream.



Land surface temperature changes control the influence of the East jet stream in this level. Due to receiving energy, the center of this Embayment has changed to a thermal Embayment at this time of year in Earth's surface that its secondary center has been drawn to the Southern parts of Iran.

Fig. 13. Map of wind flows and distribution of geo-potential height at 500 hpa on 4th, 5th and 6th August, 2008. High density stream winds intensified the speed of flow lines that appeared as jet streams.

5. Conclusion

Sea Sand Ocean's surface temperature is considered as an effective controlling factor in global climate. Indian Ocean is as a source of moisture for southeast of Iran due to summer precipitation. Summer rainfall patterns have played roles in this region, including the convergence of the wind in southeast of Iran, and the divergence of wind in the southeast of Arabian Peninsula in first pattern, the above circumstances as well as high temperatures of sea surface in second pattern, and high sea surface temperature and the monsoon east jet stream in third pattern. The results of analysis in this paper indicated that rainfall in the southeast of Iran has three different patterns in sea surface and upper levels of the troposphere. In this patterns, the wind convergence at the sea surface and divergence wind at the middle levels were evident and so obvious. Furthermore, the role of Indian Ocean sea surface temperature is another significant factor in creating precipitation. Also east monsoon jet streams intensified divergence at the middle levels of the troposphere. Mid-summer (August) showers were influenced by eastern jet stream as well as wet and shallow summer monsoon flows. While, rainfall in early summer (June) was mostly affected by the ocean surface temperature. The correlation between positive ocean surface temperature anomalies and periods of rain shows its effects in the rainfall. Advection of moisture in the patterns indicates that the transfer of moisture can be both directly from the Indian Ocean and indirectly from the Bay of Bengal carried along the monsoon currents. Wind convergence fields were seen at Earth’s level on the Jazmurian hole and north of the Strait of Hormuz, and more divergence fields in the West of Indian subcontinent were observed. In the west of India low height closed center formed on Pakistan on a 500 hpa level with deep planetary motion that played an effective role in the formation and development of Earth surface convergence zone. With the formation of convergence region in this level, dynamic factors were added to thermal factors in the lower levels and strengthened the convergence field of sea surface. In the north of Pakistan, east of Afghanistan and central region of Iran, high altitude centers by moving anticyclone have led to an increase in the pressure gradient. Vicinity of these two cores has led to the alignment of air flow from east to west. The low planetary motion and its alignment with the Northern Streams are the most important factors needed for the moisture transfer and created required conditions in this period. So we can say that, the most influential factor in rainfall occurring in the southeast of Iran is the moisture from the Indian Ocean, which is due to its surface temperature and convergence and divergence conditions in the mid levels of troposphere in summer, which caused a significant rainfall event in the region. Finally, the present study is unique in its use of factors. These factors have not been used in any other research yet.

References

1. Bollasina, M.; Nigam, S. (2009). Indian Ocean sst, evaporation, and precipitation during the South Asian summer monsoon in IPCC-AR4 coupled simulations. Climate Dynamics, 33: 1017–1032. DOI: 10.1007/s00382-008-0477-4.
2. Byeong, H.; Kyung, J. (2015). Observed changes of global and western Pacific precipitation associated with global warming SST mode and mega ENSO SST mode. Climate Dynamics, 45: 3067-3075. DOI: 10.1007/s00382-015-2524-2.
3. Chloe, P.H.; Pascal Terray, S.; Bastien, M.; Takeshi, I.; Tomoki, T.; Toshio, Y. (2014). Impacts of Indian Ocean SST biases on the Indian Monsoon as simulated in a global coupled model. Climate Dynamics, 42: 271-290. DOI: 10.1007/s00382-013-1671-6.
4. Dietmar, D. (2011). An objective analysis of the observed spatial structure of the tropical Indian Ocean SST variability. Climate Dynamics, 36: 2129-2145. DOI: 10.1007/s00382-010-0787-1.
5. www.esrl.noaa.gov/psd.
6. Ghyslaine, B.; Pascal, T.; Serbastien, M. (2012). Robustness of SST teleconnections and precursory patterns associated with the Indian summer monsoon. Climate Dynamics, 38: 2143-2165. DOI: 10.1007/s00382-011-1100-7.
7. He Ji, Y.; Jingjing, U.; ShenXin, Y. (2007). Impacts of SST and SST anomalies on low-frequency oscillation in the tropical atmosphere. Advances in Atmospheric Sciences, 24(3): 377-382. DOI: 10.1007/s00376-007-0377-2.
8. Hulme, K.; Hulme, M.; Kelly, M. (1993). Exploring the Links between Desertification and Climate Change. Environment, 35: 4-11. DOI: 10.1080/00139157.1993.9929106.
9. Hung, R.; Hung, P. (2009). Delayed atmospheric temperature -9 response to Enso SST role of high SST and the Western Pacific. Advances in Atmospheric Sciences, 26(2): 343-351. DOI: 10.1007/s00376-009-0343-2.
10. Jahanbakhsh Asl, S.; Zeinali, D.R.; Banafsheh, M.I.; Babaeian, D.R. (2012). The effect of fluctuations of the Mediterranean Sea surface temperature in rainfall of the western half of Iran. Journal of Geographical Society of Iran, 1: 161-176. [in Persian]
11. Jasti, S.; Chowdary, A.P.; SayantaniOjha C.G. (2015). Role of upper ocean processes in the seasonal SST evolution over tropical Indian Ocean in climate forecasting system. Climate Dynamics, 45: 2387–2405. DOI: 10.1007/s00382-015-2478-4.
12. Khosravi, M.; Saligheh, M.; Sabbagh, B. (2011). The impact of sea surface temperature anomalies of the Arabian Sea on rainfall of Iran’s southeastern coasts in Autumn and Winter. Tabriz, Journal of Geography and Planning, 37: 81-59.
13. Krishnamurthy, L.; Krishnamurthy, V. (2015). Decadal and interannual variability of the Indian Ocean SST. Climate Dynamics, 46: 57-70. DOI: 10.1007/s00382-015-2568-3.
14. Ming yue, Ch.; Arun K.; Wanqiu, W. (2015). A study of the predictability of sea surface temperature over the tropics. Climate Dynamics, 44: 1767–1776. DOI: 10.1007/s00382-014-2187-4.
15. Nazemosadat, J. (1998). The study of sea surface temperature of the Persian Gulf in on rainfalls in south of Iran. Nivar, 38: 46-33.
16. Nazemosadat, J.; Ghasemi, M.A.R. (2004). The effect of fluctuations of the Caspian Sea surface temperature on precipitation in the north and southwest areas of Iran. Journal of Science and Technology of Agriculture and Natural Resources, 4: 1-14.
17. Rao, J.; Rongcai, R. (2015). A decomposition of ENSO’s impacts on the northern winter stratosphere: competing effect of SST forcing in the tropical Indian Ocean. Climate Dynamics, 46: 3689-3707. DOI: 10.1007/s00382-015-2797-5.

18. Renguang, W.; Song, Y.; Zhiping, W.; Gang, H.; Kaiming, H. (2012). Inter-decadal change in the relationship of southern China summer rainfall with tropical Indo-Pacific SST. Theoretical Applied Climatology, 108: 119-133. DOI: 10.1007/s00704-011-0519-4.
19. Rezaei, B.; Jahanbakhsh, M.S.; BayatiKhatibi, M.; Zeinali, B. (2010). Prediction of Autumn and Winter rainfall in the Western half of Iran, using the Mediterranean SST in Summer and Autumn. Natural Geographical Studies: 47-62.
20. Saligheh, M. (2006). Mechanisms of precipitation in the southeast of Iran. Geographical Studies. 55: 1-12.
21. Shenoi, S.S.C.; Nasnodkar, N.; Rajesh, G.; Jossia, J.K.; Suresh Almeida, A.M. (2009). On the diurnal ranges of Sea Surface Temperature (SST) in the north Indian Ocean. Journal of Earth System Science, 118(5): 483-496. DOI: 10.1007/s12040-009-0038-1.
22. Zhang, Q.l.; Weng, X.; Cheng, M. (2001). Regional features of long-term SST variation in the western Pacific warm pool area. Chinese Journal of Oceanology and Limnology, 19(4): 312-318. DOI: 10.1007/BF02850734.