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The influence of Atlantic-Eurasian teleconnection patterns on temperature regimes in South Caspian Sea coastal areas: a study of Golestan Province, North Iran

Ghanghermeh, A.[1], Roshan, G.R. [1*] and Al-Yahyai, S.[2]

[1] Department of Geography, Golestan University, Gorgan, Iran
[2] Oman National Weather Service, Public Authority for Civil Aviation, Muscat, Oman

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ABSTRACT: The main objective of this study was to reveal the impact of nine climate indices on temperature changes and climate oscillations in Golestan Province along the southern coast of the Caspian Sea. Climate indices data from across the Atlantic-Eurasian sector were collected from the NCEP/NCAR, the Climate Prediction Centre (CPC) and the Climatic Research Unit (CRU) over a period of 40 years (1971-2010). The climate indices are then compared and correlated with temperature observations from 47 weather stations collected from meteorological and energy organizations. The correlations are based on the 12-month moving average. The study results show a significant increasing temperature trend in most months over different regions of Golestan. For maximum temperature, a significant increasing trend was seen in 55.64, 41.8 and 40% of the land area in the province during August, June and July, respectively. In general, summer had the most significant maximum-temperature trends, with an average of 37.8% of the land area. On the other hand, increasing minimum-temperature trends were seen in 58% of the land area of the province compared to the other seasons. It was concluded that there is high correlation between climate indices and temperature components. The correlation coefficients obtained for various indices including North Atlantic Oscillation (NAO), North Sea Caspian Pattern (NCP), Arctic Oscillation Index (AO), East Atlantic (EA), East Atlantic/West Russia (EATL/WRUS), Atlantic Multi-decadal Oscillation (AMO), North Tropical Atlantic (NTA), Polar/Eurasia (PE), and Scandinavia teleconnection index (SCAND) suggest an inverse relationship between these indices and temperature components. Therefore, the higher the values of these indices, the lower the temperature values, and vice versa.

Key words: Climate indices, Climate oscillation, Golestan province,Temperature trend

INTRODUCTION

It is very important to understand the relationship between low-frequency variations in large-scale atmospheric circulation driven by the oceans and high-latitude hydro-climatic variability at a regional level. This relationship can be used to assess projections of climate change at a regional scale and to design measures for climate-change adaptation. Some year-to-year variation in climate is associated with patterns that are coherent on a large scale, and this has provided a useful basis for skilful prediction (Hammer et al., 2001). Teleconnection patterns are the preferred modes of low-frequency (or long-timescale) natural variability of atmospheric circulation with geographically fixed centres of action (Hatzaki et al., 2007).

Iran is characterized by its arid and semi-arid climate. The study of temperature variability and seasonal prediction of

* Corresponding author E-mail: ghr.rowshan@gmail.com

temperature over Iran is important because of its impact on agriculture, livestock, forestry, water resources, tourism, construction and many other local activities. Iran depends on agriculture in its economy, and temperature fluctuations have a remarkable impact especially on plant growth and development during sensitive stages, such as flowering and harvesting.

Several studies in the past 15 years have indicated that variations in monthly and seasonal temperature over a large part of the northern hemisphere are controlled by various teleconnection patterns such as North Atlantic Oscillation (NAO), Arctic Oscillation (AO), North Sea-Caspian Pattern (NCP) and El-Nino Southern Oscillation (ENSO) (Del Rio, 2013).

The relation between different climate variability indices, especially the ENSO, and precipitation over Iran has been investigated by Nazemosadat and Cordery (2000), Nazemosadat and Ghasemi (2004), Nazemosadat et al. (2006), Soltani and Gholopoor (2006), Sabziparvar et al. (2011), Shirmohammadi et al. (2012) and Abolhasan and Maryam (2013). Nazemosadat and Cordery (2000) investigated the relationship between the ENSO and autumn rainfall in Iran over the period 1951-1990. A negative correlation was found all over Iran. In addition, it was noticed that more rainfall is experienced during El Nino compared to La Nina periods. Nazemosadat and Ghasemi (2004) quantified the impact of the ENSO based on the intensity and occurrence probability of dry and wet periods in Iran during boreal autumn and winter. Three phases (warm, cold, and neutral) were defined based on the status of the Southern Oscillation (SO), and precipitation composites were constructed for each phase. Sabziparvar et al. (2011) investigated the impacts of ENSO on reference evapotranspiration variability in some warm climates of Iran based on 50 years of meteorological observations. It was concluded that the teleconnection impact of ENSO on reference evapotranspiration in warm arid regions (sites in southern Iran) was more significant than in warm humid regions. Soltani and Gholopoor (2006) investigated the relationship between ENSO and rainfall and temperature at six sites in Iran. Significant correlation was found between southern SO index and precipitation and temperature during autumn and winter. The warm phase of ENSO (El Nino) was found to be correlated significantly with drier winters, while negative ENSO was associated with warm winters.

Del Rio et al. (2013) investigated the monthly, seasonal and annual trend of mean temperature and its teleconnection with climate indices of Pakistan. Significant teleconnection was found during March, April and May with NOA, ENSO and NCP. During the monsoon period, NOA showed higher correlation with the temperatures at stations affected by the monsoon.

Ghasemi and Khalili (2006) discussed the effect of Arctic Oscillation (AO) on the winter surface-air temperature over Iran based on 50 years of data using Median Sequential Correlation Analysis. It was found that air temperature was negatively correlated to the winter AO index for most parts of Iran. The winter AO index accounted for about 14% to 46% of the winter surface-temperature variance. The positive (negative) SAT anomaly was found to be associated with the onset of the negative (positive) phase.

Ghasemi and Khalili (2008) investigated possible linkages between the NCP index and winter temperature variability over Iran. It was found that NCP has a strong negative correlation with the winter temperature in Iran. It was also found that combined NCP and Arctic Oscillation can provide major patterns for explaining Iranian winter temperature variability.

Apart from the few studies mentioned, the relationships between oceanic-atmospheric indices and temperature variability over Iran have not yet been comprehensively explored. The main objective of this study is to investigate the impact of nine climate indices on temperature changes and climate oscillations over Golestan Province.

Study area

Golestan Province is located in the North-East of Iran and South of the Caspian Sea. It has an area of 20,438 km^2, representing 1.3% of the total area of Iran. Geographically, Golestan is located at 36° 30’N to 38° 7’N and 53° 51’E to 56° 21’E (Fig.1). The northern parts of the province are located below sea level. Due to its complex terrain, the province can clearly be divided into two parts: lowlands and highlands. The shorelines and coastal plains of the Caspian Sea are bounded by the Alborz Mountains, which decrease in height towards the North-East. This mountain chain extends for a long distance, with a few valleys. The province is characterized by its remoteness, its proximity to the sea and the deserts of Turkmenistan, and its local and regional wind regime. It has a long, hot summer lasting up to six months and short, mild and rainy winters. During winter, because of the advancing cold air mass, there is an increase in the number of days Golestan experiences frost. There is rarely snowfall, however. Due to low humidity, the intensity of heat increases, leading to increased variation between day and night temperatures as well as the coldest and warmest months of the year. The large difference between daytime and night-time temperatures also leads to cold-climate conditions and thus cold-climate varietal production.

In the North-East of the province, marked changes occur in the moist climate of the Caspian Sea, especially to the East between the Gorgan River and the Turkmenistan border, the humid climate gradually becoming warmer and semi-arid (semi-deserts), where the heat is exacerbated by ongoing drought and annual rainfall decreases. This is due to the area’s proximity to the Caspian Sea, the low altitude of the eastern Alborz Mountains, the width of the coastal plains, and the proximity to the Karakum Desert in central Asia.

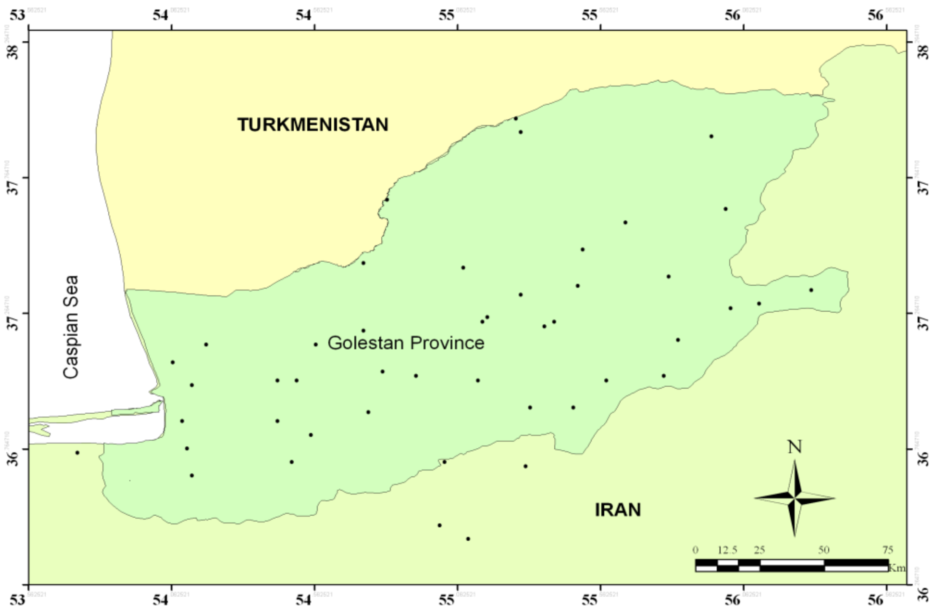

Fig. 1. Location of Golestan Province

MATERIALS & METHODS

The main objective of this study is to identify some possible teleconnection patterns between the air-temperature component and some climate anomalies. Minimum and maximum temperature data derived from 47 measurement stations were used to investigate the relationship. Climate temperature data (1971 to 2010) were provided by the Iran Meteorological Organization (IRIMO) and the Ministry of Energy. In order to ensure unified data for the 47 stations, the interface-detector method kriging was used. Several homogeneity tests, including the Kolmogorov-Smirnov test, were conducted. Then, the minimum and maximum temperature trends were calibrated and analysed, using linear regression at 95% and 99% confidence levels. The process was conducted based on monthly data.

Data on nine teleconnections and climate indices were collected from NCEP/NCAR, the Climate Prediction Centre (CPS) and the Climatic Research Unit (CRU). The nine indices were then used to evaluate the relationship to the regime changes and temperature patterns of Golestan Province. The selected climate indices cover the Atlantic-Eurasian region, including North Atlantic Oscillation (NAO), North Sea Caspian Pattern (NCP), Arctic Oscillation Index (AO), East Atlantic (EA), East Atlantic/West Russia (EATL/WRUS), Atlantic Multi-decadal Oscillation (AMO), North Tropical Atlantic (NTA), Polar/Eurasia (PE), and Scandinavia (SCAND). It should be mentioned that the correlations were based on a 12-month moving average to remove the seasonal effects and the maximum- and minimum-temperature measurements. Local impacts on temperature trends and climatic indices were minimized by this approach. Pearson's correlation was then used to find any significant relationships between these two parameters. In order to compare the relations between the temperature changes and the different phases of each index, the mean time-series temperature was calculated for each phase and then compared to the long-term average to determine the temperature-change phase.

During the analysis of the data, two maps were generated. The first map represents the maximum and minimum variations. This map is useful to determine which region of the province shows either positive or negative trends for different months. The second map is the map of correlation between the maximum and minimum temperatures of the selected stations and each of the nine climate indices.

RESULTS & DISCUSSION

The average maximum daily temperature variation

Based on the 40-year time-series data, it was found that January showed a significant increasing trend of maximum temperature over 17% of the province (Fig. 2). Similarly, both February and March showed a significant increase over a wider area (30% of the province) and the increase covered both highlands and lowlands in the western parts of the region. On the other hand, April showed a significant decrease over 11% of the area in highlands and Middle East regions. During May, 13% of the province experienced an increase in temperature trends. June and July also showed a significant increase over the northern parts of the western half of province, as well as the central and eastern parts. August showed the widest decrease. An 18% increase was seen in the temperature during September over the North and North-West of the province. A significant increase can be seen during October over only 15% of the area. On the other hand, there was no significant increase during November compared to the temperature decrease over the North-East of the province. The temperature trends in the North-West and North-East of the province over different regions are illustrated in Figure 2.

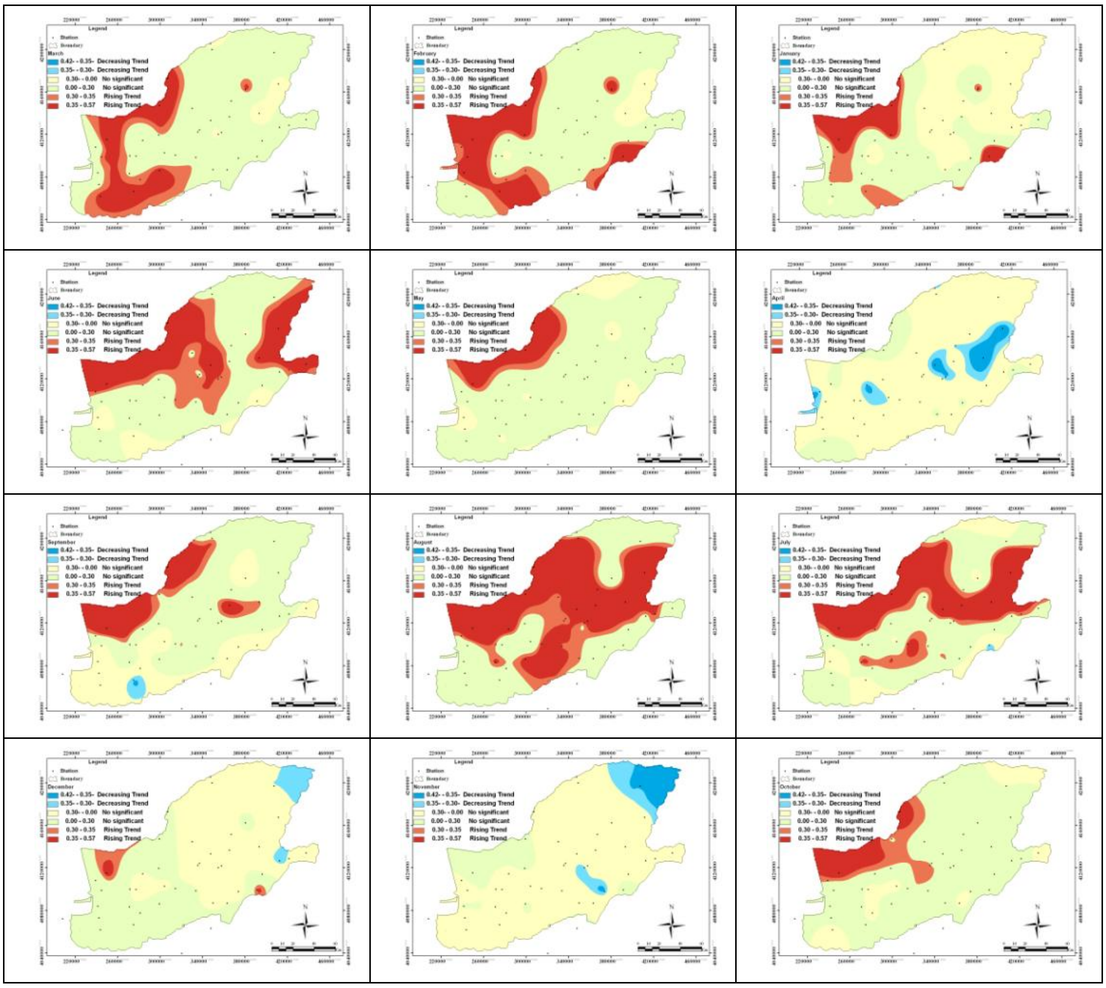

Fig. 2. 40-year average maximum temperature trends classification in Golestan Province for different months

The average minimum night-time temperature

Figure 3 shows the average minimum night-time temperature based on the 40 years of data for the different months. During January, there is a significant increasing trend of minimum temperature covering about 39% of the province. The increasing trend spreads from the centre to the north-eastern parts of the province. The increasing trend expanded over 55% of the land during February. On the other hand, 5% of the area showed a decreasing trend.

The affected area was smaller (35%) in size during March compared to February. On the other hand, there was a decreasing trend covering 8.7% of the area. April, when spring starts, showed increasing night-time temperature in northern, western and south-western parts of the province. According to the trend analysis, Figure 3 shows the affected area (increasing trend) increasing in size during May. On the other hand, 2% of the area experienced a decreasing trend. June showed the highest increase in minimum temperature trend, covering 64% of the area, while 6% of the area showed a decreasing trend. Lower increasing effect (47%) and higher decreasing effect (19%) were observed during July. During August, the covered area changed to 57% and 18% for increasing and decreasing trends, respectively. The figures for September were 70% and 2%, respectively. Autumn showed a significant increase during October for about 75% of the area. A decreasing trend can be seen during October over 6% of the area. About 21% and 30% of the total area of the province showed a significant positive trend during November and December, respectively.

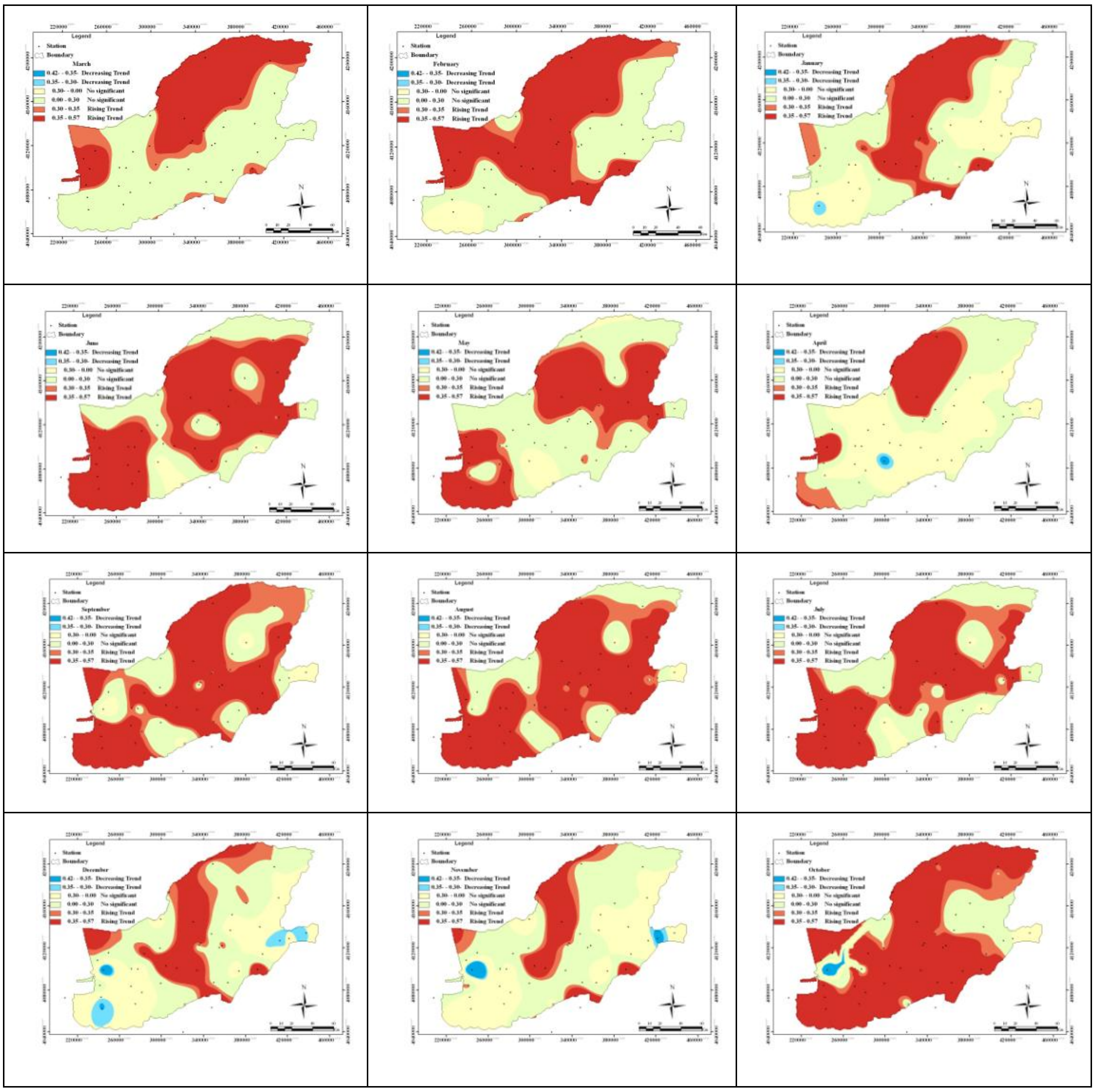

Fig. 3. 40-year average minimum temperature trends classification in Golestan Province for different months

Atlantic Multi-decadal Oscillation (AMO)

AMO describes a long-term change in the sea surface temperature over the North Atlantic Ocean. There are warm and cold phases of the oscillation, where each phase may last 20-40 years with 1°F difference (Aondover, 2013). It can be seen from Figure 4 that there is a direct and significant relationship between AMO and maximum (right) and minimum (left) temperature, covering 91% and 98% of the area, respectively. Therefore, during the positive phase of the index, higher maximum and minimum temperatures are expected. It was found that the correlation coefficient between AMO and the 12-month moving average of maximum temperature corresponds to 0.48 by 99% confidence interval. However, a more significant relationship can be found using Pearson's correlation coefficient with r=0.78 and 99% confidence interval. During 1971 and 2010, there were three positive phases and two negative ones (Fig. 5). It was noticed that during the negative phase of AMO, the time series of both minimum and maximum temperatures experienced above-average temperatures one time and below-average temperatures three times. On the other hand, both experienced above-average temperatures two times during the positive phase (Table 1).

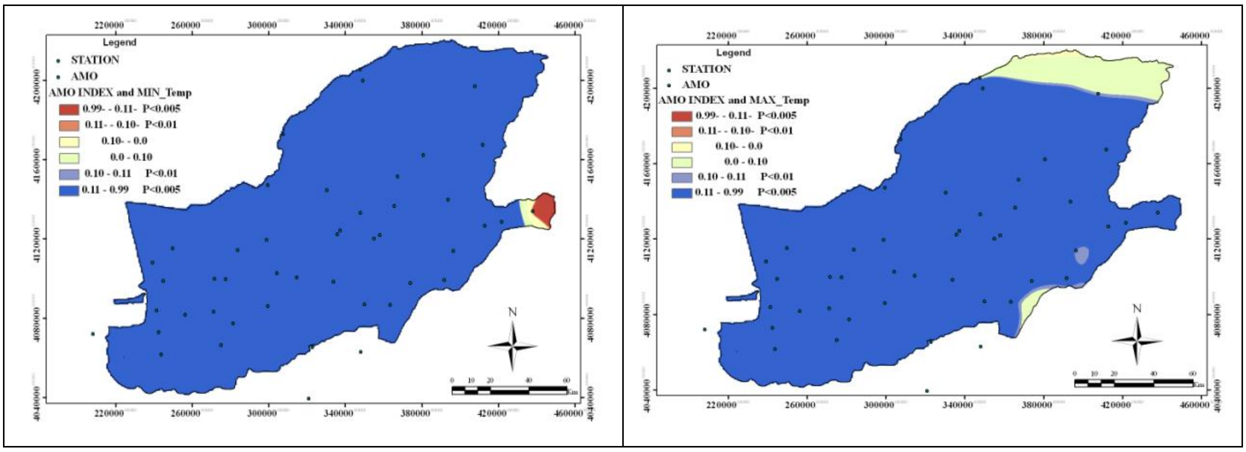

Fig. 4. The correlation coefficient between AMO and minimum (left) and maximum (right) temperature trends: (P stands for p-value, and different colours indicate different values of the Pearson correlation coefficient)

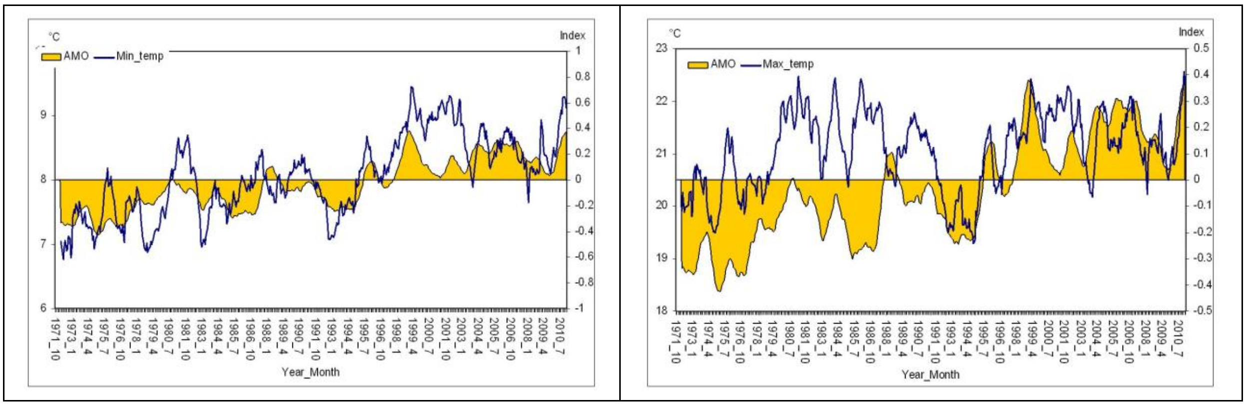

Fig. 5. Long-term average minimum (left) and maximum (right) temperature trends for AMO

The Arctic Oscillation (AO) Index

AO, known also as Northern Hemisphere Annular Mode (NAM), is a non-seasonal sea-level pressure variation of 20N latitude. It is characterized by pressure anomalies of one sign in the Arctic with the opposite anomalies centred about 37–45N. During its positive phase, below-average geopotential heights are experienced (Andover, 2013).

Based on the analysis shown in Figure 6, a clear significant relationship between AO and maximum- and minimum-temperature components is seen. However, the correlation coefficient is negative, indicating an inversely proportional relationship. Therefore, during negative phases of AO, higher temperature occurs. There was no significant relationship between AO and maximum temperature over the eastern and north-western parts of the province and no relation between AO and minimum temperature for those areas located in the north-western parts of the province. Based on the definition of phase, AO index has had seven positive and eight negative phases over the 40-year period of study (Fig. 7). It was noticed that during the negative phase, the minimum temperature was above average five times and below average three times. On the other hand, the maximum temperature was above average seven times and below average one time only. During positive phases, both the maximum and minimum-temperature time series experienced above-average temperatures three times and below-average temperatures four times, respectively, as shown in Table 1.

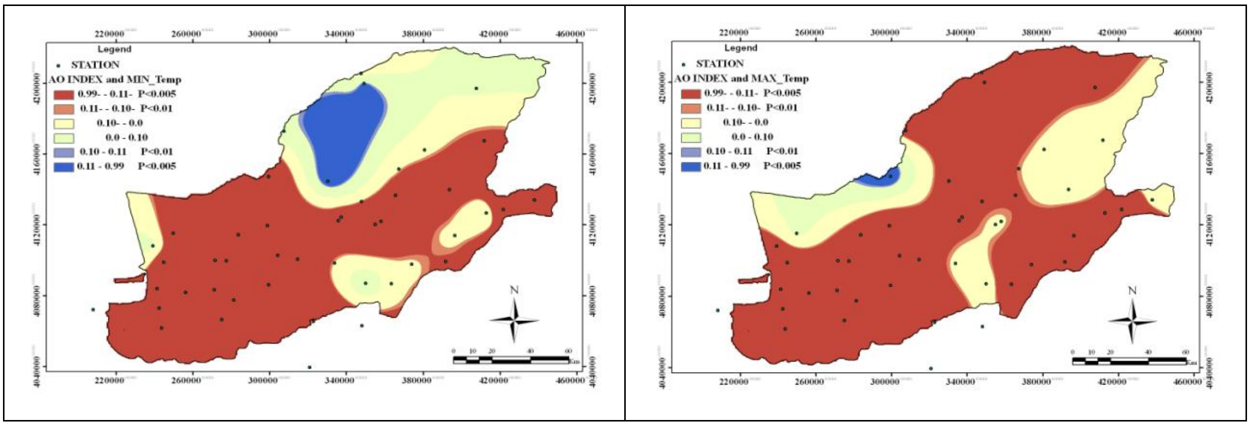

Fig. 6. The correlation coefficient between AO and minimum (left) and maximum (right) temperature trends (P stands for p-value, and different colours indicate different values of the Pearson correlation coefficient.)

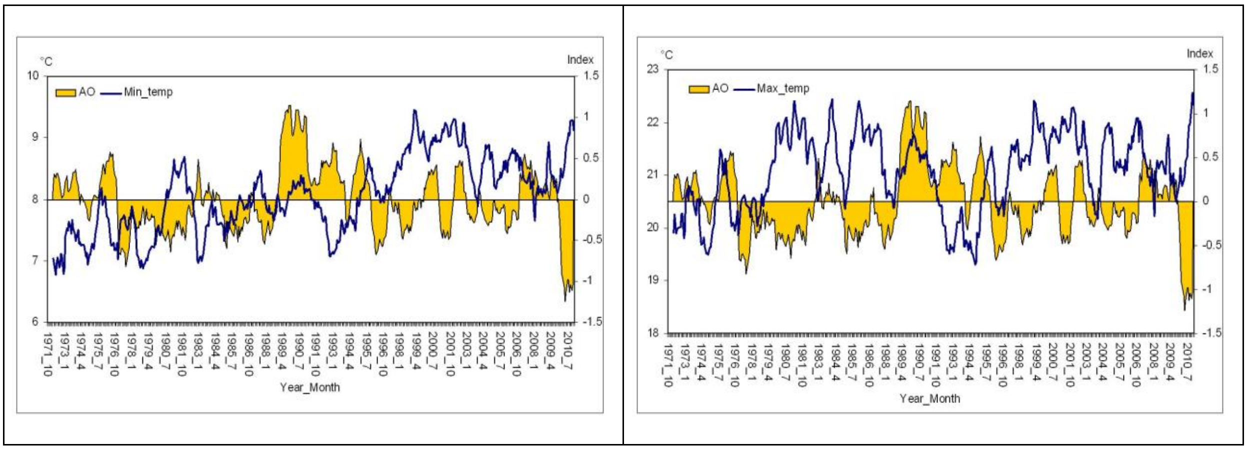

Fig. 7. Long-term average minimum (left) and maximum (right) temperature trends for AO

The East Atlantic (EA) pattern

EA is a prominent mode among low-frequency variability modes over the North Atlantic. It appears during all months except May–August and has a similar structure to NAO. Due to these similarities, the EA pattern is often mistaken as a slightly “southward-shifted” NAO pattern (Aondover, 2013).

During the study, it was evaluated that 91% and 94% of the stations showed significant relations between EA and maximum and minimum temperatures, respectively, as shown in Figure 8. With a level of confidence of 99%, the correlation coefficients between EA and the 12-month moving average of maximum and minimum temperatures are r=0.36 and r=0.48 , respectively. During 1971 to 2010, there were six positive and nine negative phases for EA (Fig. 9). During negative phases, the minimum-temperature time series showed above-average temperature behaviour three times and below-average temperatures six times. The maximum-temperature time series showed above-average temperature behaviour four times and below-average temperature behaviour five times for the same phase. On the other hand, both maximum- and minimum-temperature time series showed above-average temperature behaviour five times and below-average temperature behaviour one time during the positive phase (Table 1).

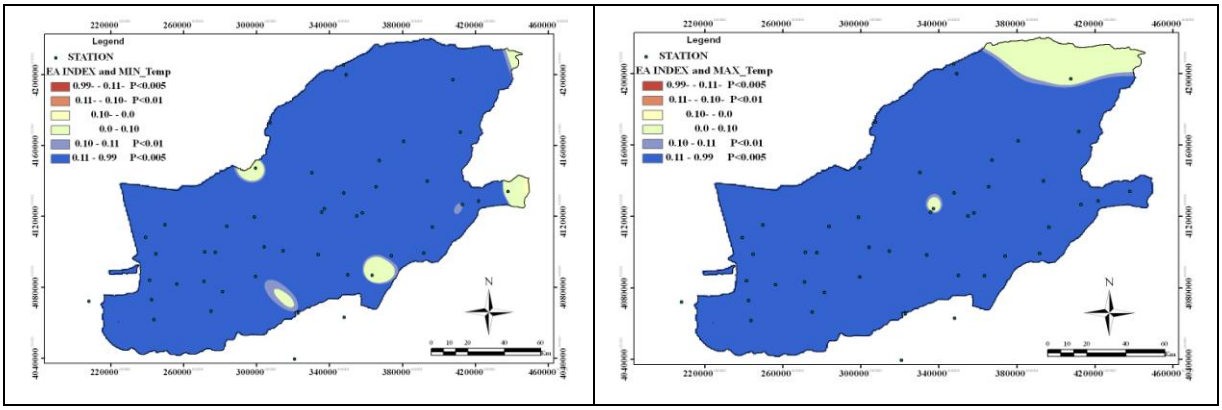

Fig. 8. The correlation coefficient between EA and minimum (left) and maximum (right) temperature trends (P stands for p-value, and different colours indicate different values of the Pearson correlation coefficient.)

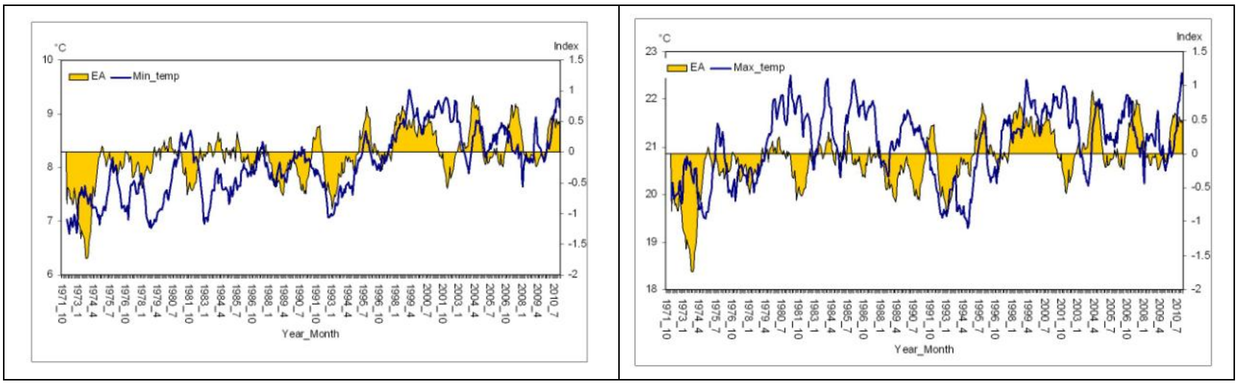

Fig. 9. Long-term average minimum (left) and maximum (right) temperature trends for EA

The East Atlantic / West Russia (EATL/ WRUS) pattern

The EATL/WRUS pattern is one of the most prominent patterns affecting Eurasia during most of the year. This pattern is prominent in all months except June-August. In winter, two main anomaly centres, located over the Caspian Sea and Western Europe, comprise the East Atlantic/West Russia pattern. A three-celled pattern is then evident in the spring and autumn, with two main anomaly centres of opposite signs located over western/north-western Russia and over north-western Europe. The third centre, having the same sign as the Russia centre, is located off the Portuguese coast in spring but exhibits a pronounced retrogression towards Newfoundland in autumn (Aondover, 2013). Figure 10 shows that there is a significant relationship between maximum and minimum temperatures and EATL/WRUS index over 96% and 87% of the stations, respectively. The obtained results show that both are inversely related. Therefore, during the positive phase of EATL/WRUS lower temperature occurs. Correlation coefficients of r= -0.33 and r= -0.38 are shown between the EATL/WRUS and the 12-month moving average of maximum and minimum temperatures, respectively. There were eight positive phases and ten negative phases during 1971 to 2010 (Fig. 11). During the negative phase, the minimum-temperature time series showed above-average temperatures six times and below-average temperatures four times. On the other hand, maximum temperature was above average seven times and below average three times. During positive phases, minimum temperature was above average three times and below average five times. Finally, maximum temperature was above average two times and below average six times, respectively (Table 1).

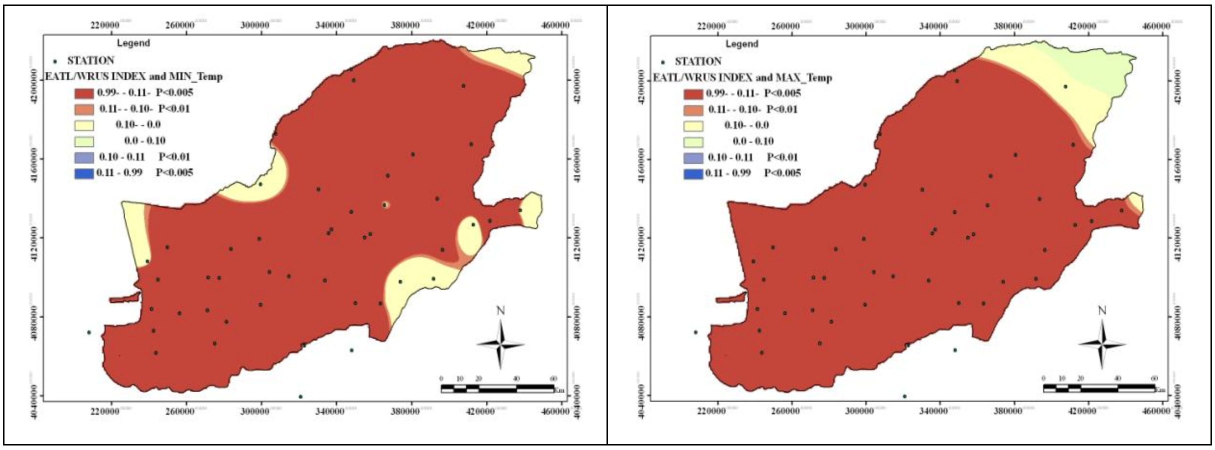

Fig. 10. The correlation coefficient between EATL/WRUS and minimum (left) and maximum (right) temperature trends (P stands for p-value, and different colours indicate different values of the Pearson correlation coefficient.)

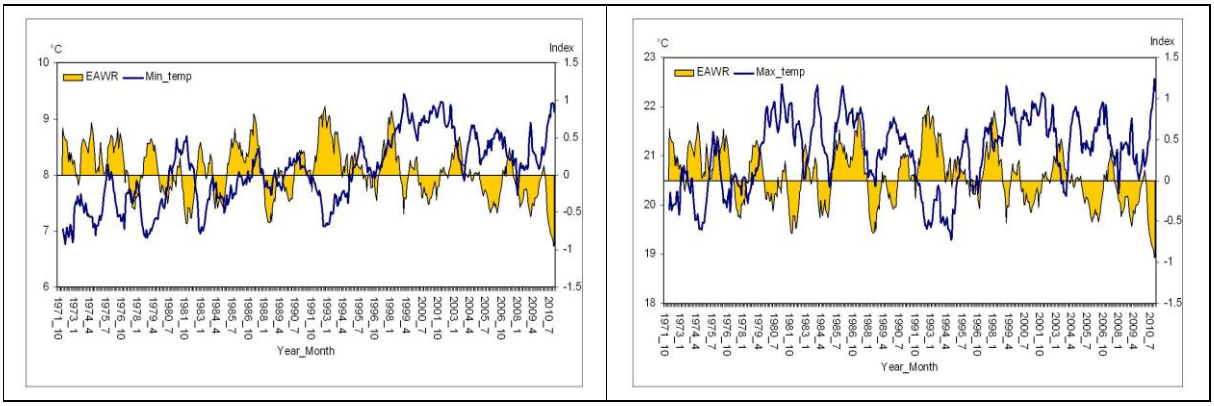

Fig. 11. Long-term average minimum (left) and maximum (right) temperature trends for EATL/WRUS

North Atlantic Oscillation (NAO)

NAO is based on the sea-level pressure difference between the subtropical (Azores) high and the subpolar low. During the positive phase of NAO, below-normal heights and pressure across high latitudes of the North Atlantic and above-normal heights and pressure over the central North Atlantic, the eastern United States and Western Europe are expected. Both phases of the NAO are associated with basin-wide changes in the intensity and location of the North Atlantic jet stream and storm track, and in large-scale modulations of the normal patterns of zonal and meridional heat and moisture transport, which in turn result in changes in temperature and precipitation patterns often extending from eastern North America to western and central Europe (Aondover, 2013).

NAO correlation with maximum and minimum temperatures over Golestan shows correlation coefficients of r= -0.25 and r= -0.39, respectively, with a 99% confidence interval. The correlation shows an inverse relation between NAO and maximum and minimum temperatures over 91% and 72% of the stations, respectively. Figure 12 shows also that the highest correlation is seen between the minimum-temperature component and NAO. During 1971 and 2010, there were eight positive phases and ten negative phases for NAO (Fig.13). The longest negative phase was the last one, which lasted for about 40 months. The longest positive phase was the one covering the period from 1989 to 1993 (53 months). During the positive phase, minimum temperature showed below-average temperature behaviour five times and above-average temperature behaviour two times. On the other hand, during the negative phase, both minimum and maximum temperatures showed below-average temperatures behaviour four times and above-average temperature behaviour six times (Table 1).

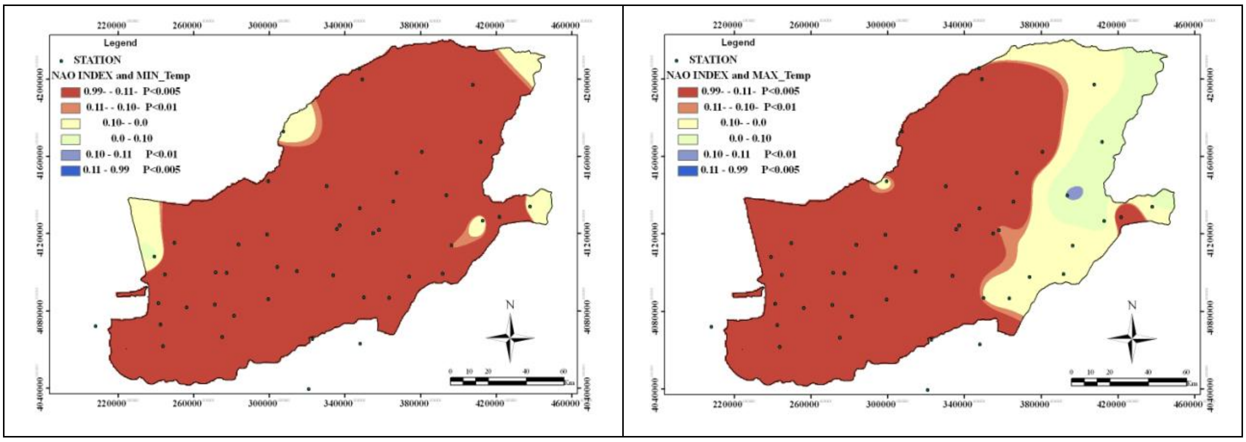

Fig. 12. The correlation coefficient between NAO and minimum (left) and maximum (right) temperature trends (P stands for p-value, and different colours indicate different values of the Pearson correlation coefficient.)

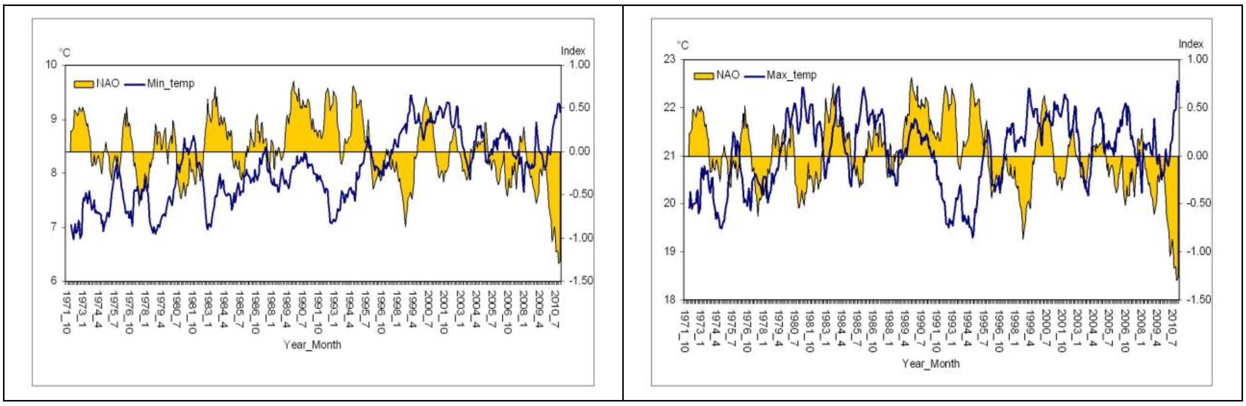

Fig. 13. Long-term average minimum (left) and maximum (right) temperature trends for NAO

The North-Sea Caspian Pattern (NCP)

NCP is an upper-level atmospheric teleconnection between the North Sea and Caspian regions centred between 0° and 55° and 10°E, 55°N for its north-western pole and between 50°E, 45°N and 60°E, 45°N for its south-eastern pole (Aondover, 2013). Negative correlation is shown in Figure 14 between the 12-month moving average of NCP index and minimum and maximum temperatures over 64% and 96% of the stations, respectively. It is worth mentioning that the negative correlation coefficients are dominantly located in the northern half of the province. Correlation coefficients between NCP and the 12-month moving average of maximum and minimum temperatures were found to be r= -0.40 and r= -0.20, respectively. Based on the phase definition, NCP had six positive and eight negative phases over the 40-year period of the study (Fig. 15).

During negative phases, minimum temperature was above average two times and below average six times. On the other hand, maximum temperature was both above and below average four times. During positive phases, minimum temperature was above average two times and below average four times. On the other hand, maximum temperature was both above and below average two times (Table 1).

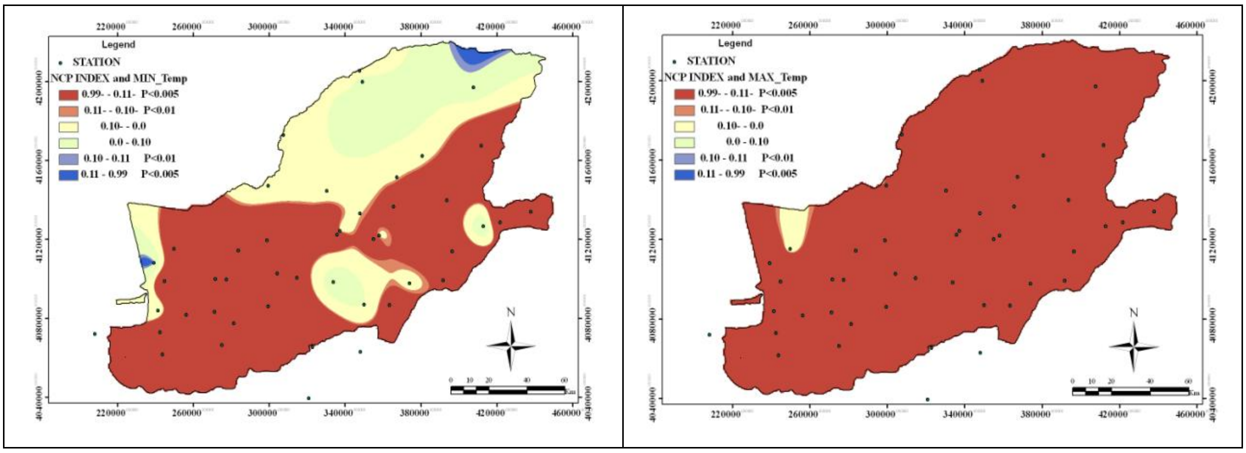

Fig. 14. The correlation coefficient between NCP and minimum (left) and maximum (right) temperature trends (P stands for p-value, and different colours indicate different values of the Pearson correlation coefficient.)

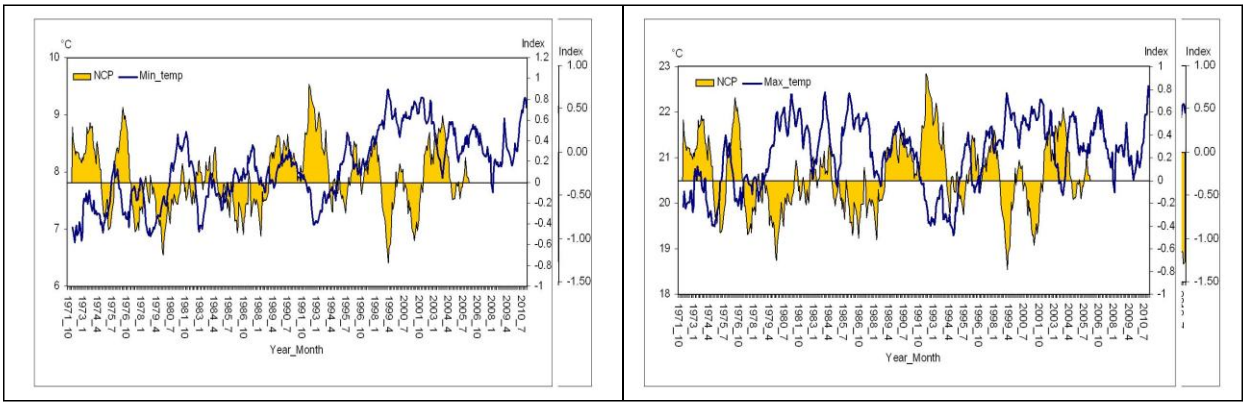

Fig. 15. Long-term average minimum (left) and maximum (right) temperature trends for NAO

Table 1. The number of increases/decreases in the mean-temperature time-series data compared to the long-term average temperature coinciding with positive or negative phases of different climate indices

Climate indices	Negative phase coinciding with minimum temperature			Positive phase coinciding with minimum temperature		
	Total frequency	the frequency of negative temperature	the frequency of positive temperature	Total frequency	the frequency of negative temperature	the frequency of positive temperature
NAO	10	4	6	8	5	3
NCP	8	6	2	6	4	2
AO	8	3	5	7	4	3
AMO	4	3	1	3	2	1
EAWR	10	4	6	8	5	3
NTA	3	3	--	5	3	2
POL/EUR	7	2	5	8	4	4
EA	9	6	3	6	1	5
SCAND	7	3	4	10	5	5

North Tropical Atlantic Index (NTA)

NTA is the time series of SST anomalies averaged over 60W to 20W, 6N to 18N, 20W to 10W and 6N to 10N (Aondover, 2013). The correlation between the 12-month moving average of NTA and the maximum and minimum temperatures of stations proved a direct significant relationship over 94% and 96% of stations, respectively. The weakest relationship between NTA and temperature components is found over the eastern and north-eastern parts of the province (Fig. 16). The correlation coefficients between NTA and the 12-month moving average of maximum and minimum temperatures were r= 0.44 and r= 0.62, respectively, with a 99% confidence interval. Based on the phase definition, there were five positive phases and three negative ones over the 40-year period of the study (Fig. 17).

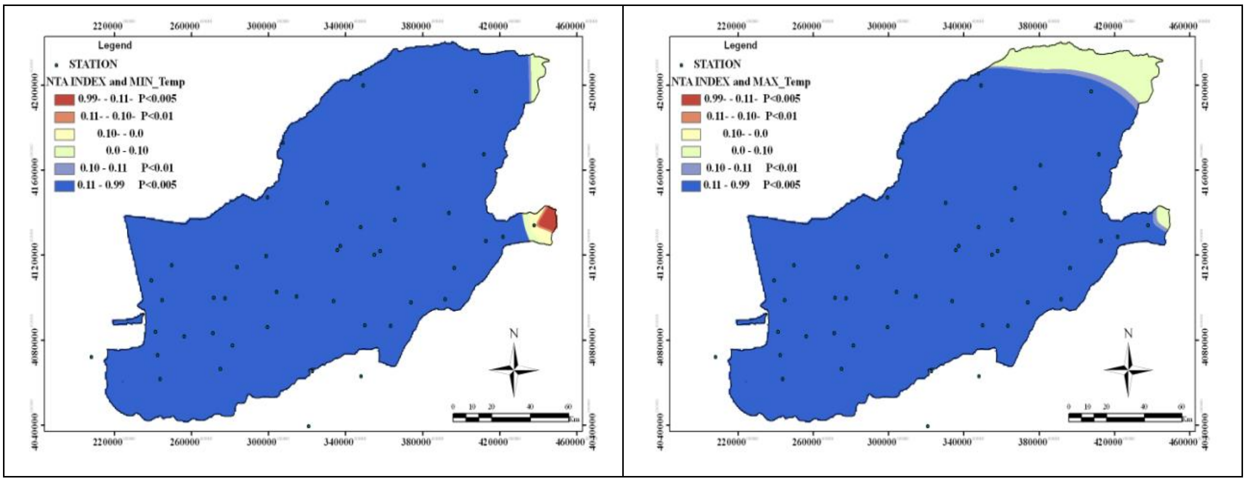

Fig. 16. The correlation coefficient between NTA and minimum (left) and maximum (right) temperature trends (P stands for p-value, and different colours indicate different values of the Pearson correlation coefficient.)

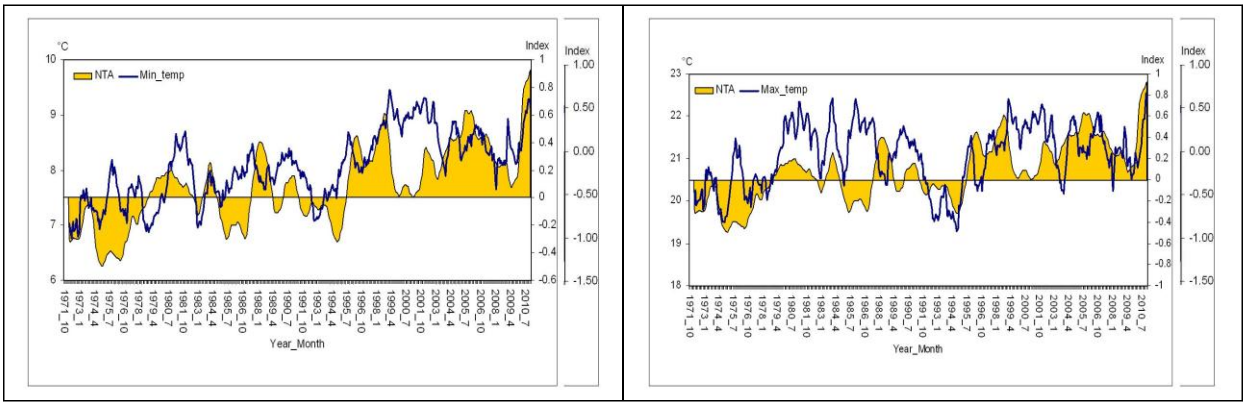

Fig. 17. Long-term average minimum (left) and maximum (right) temperature trends for NTA

The Polar/Eurasian pattern

The polar/Eurasian pattern was also evaluated in this study. The results for correlation between this index and temperature components are remarkable. The maximum-temperature component showed a higher level of significance than the minimum-temperature component in 98% of the stations. The correlation coefficient is mostly negative in this regard, showing that the higher the value of the index, the lower the temperature. There is also a negative or inverse significant relationship between the polar/Eurasian pattern and the minimum-temperature component in 89% of stations (Fig. 18). The correlation coefficients between the index of polar/Eurasian and a 12-month moving average of maximum and minimum temperatures were r= -0.35 and r= -0.27, respectively, with a significance level of 99%. The polar/Eurasian time series have eight positive phases and seven negative ones over the 40-year period of the study (Fig. 19). The minimum-temperature time series show equal-to-average behaviour five times and below-average temperatures three times during the negative phase. On the other hand, maximum temperatures were above average six times and below average one time. During the positive phase, the minimum-temperature time series showed both above- and below-average temperatures two times and the maximum temperature was above average two times and below-average six times (Table 1).

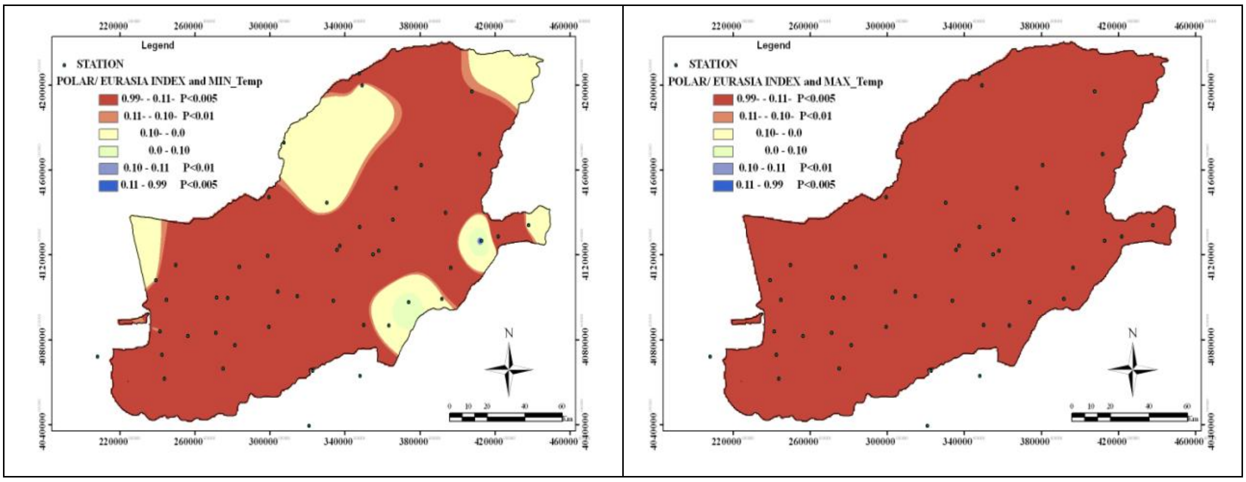

Fig. 18. The correlation coefficient between polar-Eurasia and minimum (left) and maximum (right) temperature trends (P stands for p-value, and different colours indicate different values of the Pearson correlation coefficient.)

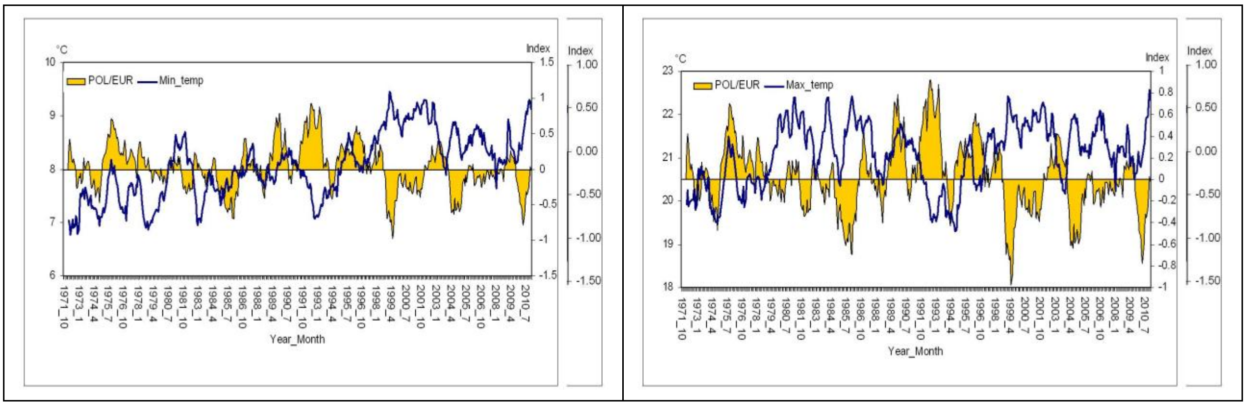

Fig. 19. Long-term average minimum (left) and maximum (right) temperature trends for polar/Eurasia

Scandinavia pattern (SCAND)

SCAND consists of a primary circulation centre spanning Scandinavia and large portions of the Arctic Ocean north of Siberia. Two additional weaker centres with opposite sign to the Scandinavia centre are located over Western Europe and over the Mongolia/Western China sector. The positive phase of this pattern is associated with positive height anomalies, sometimes reflecting major blocking anticyclones, over Scandinavia and western Russia, while the negative phase of the pattern is associated with negative height anomalies over these regions (Aondover, 2013).

SCAND is considered one of the factors with a large influence over Iran's climatic conditions. Several studies have shown that it has a remarkable relationship with the maximum temperature of Golestan. During this study, a significant negative relationship between SCAND and maximum temperatures was noticed in 100% of stations (Fig. 20). However, these results are different from those obtained from the minimum-temperature data, where only 70% of stations showed a significant inverse relationship with SCAND. The correlation coefficients between SCAND and the 12-month moving average of maximum and minimum temperatures were r= -0.40 and r= -0.25, respectively, with a significance level of 99%. The SCAND time series have experienced ten positive phases and seven negative ones during the period from 1971 to 2010 (Fig. 21). The minimum-temperature time series showed above-average temperature behaviour four times and below-average behaviour three times during the negative phase. On the other hand, the maximum-temperature time series experienced above-average temperature behaviour six times. During the positive phase, both minimum and maximum temperatures were above and below average five times (Table 1).

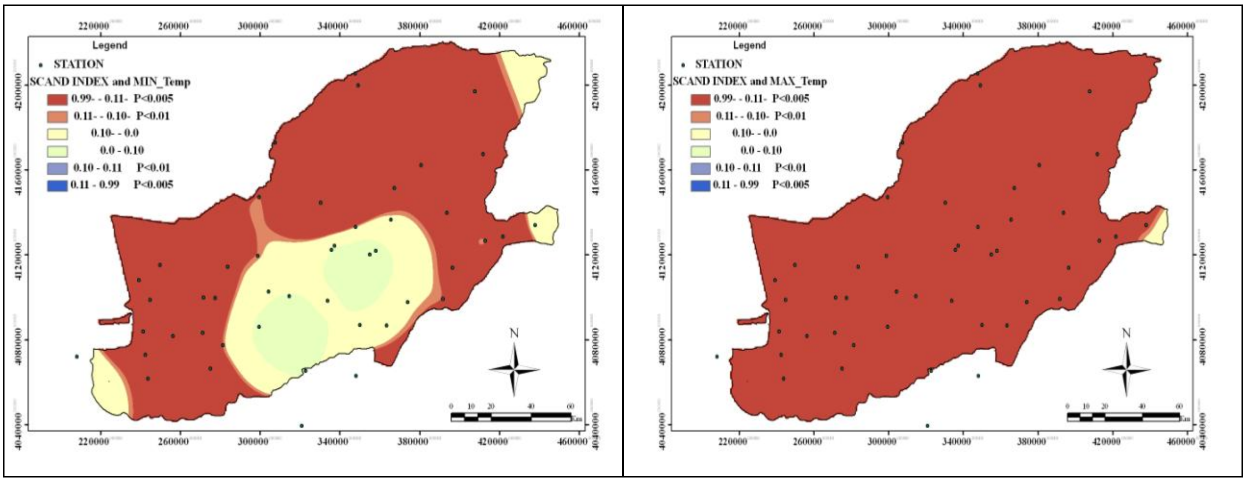

Fig. 20. The correlation coefficient between SCAND and minimum (left) and maximum (right) temperature trends (P stands for p-value, and different colours indicate different values of the Pearson correlation coefficient.)

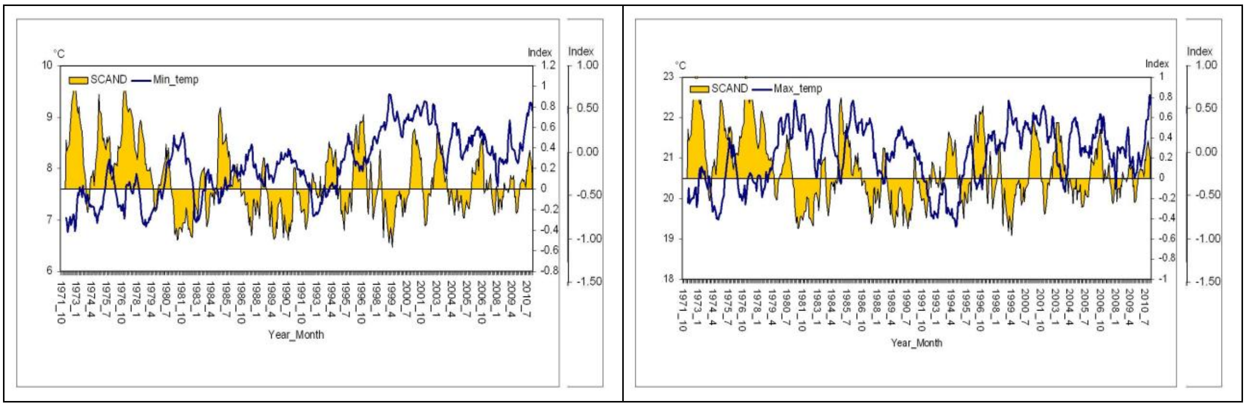

Fig. 21. Long-term average minimum (left) and maximum (right) temperature trends for SCAND

CONCLUSION

The main objective of this study was to reveal the impact of nine (NAO, NCP, AO, EAEATL/WRUS, AMO, NTA, PE and SCAND) climate indices on temperature changes and climate oscillations over Golestan Province in Iran.

The results derived from daytime daily maximum temperatures are different from those obtained from the night-time daily minimum temperatures. Minimum temperature showed significant increase in all months. The results of this study are consistent with those of studies in other areas of the world. Based on the 47 stations considered in this study, there was a significant trend of increasing temperature in most months based on average monthly maximum-temperature time series covering the period from 1971 to 2010. The maximum temperature showed a significant increasing trend over 56%, 42% and 40% of the land area during August, June and July, respectively. Seasonal analysis showed that summer had the most significant maximum-temperature trends over 38% of the land area, while autumn showed the least significant increase. On the other hand, minimum-temperature increasing trend was seen in 58%, 43%, 43% and 42% of the land area during summer, winter, spring and autumn, respectively. The results of the correlation between Atlantic-Eurasian teleconnection patterns and minimum-maximum temperature profiles of Golestan Province proved the existence of a significant relationship between these indices and those of the province. The two most significant correlations were found between minimum temperature and NTA index and between minimum temperature and EA index. The least significant two correlations were found between minimum temperature and AO index and between maximum temperature and AO index. Seven indices (AM, AO, EATL/WRUS, NAO, NCP, polar-Eurasia and SCAND) among the nine Atlantic-Eurasian indices showed an inverse relationship with the temperature components in the province. EA and NTA, however, showed a positive significant relationship with the temperature components. This could be due to the direct impact of subtropical Atlantic climates (for example the influence of the Azores and other hot high-pressure systems), which may affect some parts of the country, especially the Golestan Province. It is recommended that other teleconnection and world climate patterns, including Pacific Ocean indices, should also be analysed for Golestan Province and the results compared with those obtained from the Atlantic-Eurasian teleconnection patterns.

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