The Trend of Temperature Changes in Iranian Metropolises in the Last Three Decades

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Abstract

Global warming is a challenging issue among the world's climatologists, embraced even by politicians and the common people. In this study, the trend of temperature changes in 31 metropolises of Iran, which are generally the provincial centres of the country, has been studied in a statistical period of 35 years (1985-2019). We found that there are more temperature changes in all metropolises of Iran in winter than other seasons. In this season, the maximum temperature parameter shows a significant increase, as evidenced in Ardabil with about 9 degrees Celsius. Also, the highest amount of temperature increase in all seasons has occurred in the western and northwestern part of Iran, being of mildly cold to extremely cold climate in Iran. In general, the temperature changes more intensively from the south to the north regions. It is interesting that in the southern and coastal cities of Iran, such as Ilam, Bushehr and Shiraz, in some months, the temperature keeps decreeing. The increase in temperature of metropolises has been much more regular for the maximum temperature than the minimum temperature. Strangely, unlike all the months in November, the maximum temperature has decreased in most cities in Iran.

Introduction

As a major atmospheric variable, temperature directly affects physical and biological processes (Logan and Paul, 2001; Stahl et al., 2006; Li et al., 2013; Wu and Li, 2013). Examination of temperature in a certain place and time shows that this variable is strongly influenced by atmospheric circulation patterns. Therefore, by identifying the patterns of atmospheric circulation, we can study the changes, frequency, intensity and spatial distribution of temperature variables and express its physical reasons Vicente Serrano and Lepoz 2006, 1428). In this connection, climate change, and its association with higher greenhouse gas concentrations, has raised concerns (Boykoff and Boykoff, 2007). An increase in CO2, along with an increase in other greenhouse gases, is believed to change the Earth's energy balance. Anthropological changes in the Earth's climate associated with these increases have been confirmed and further increases are predicted (Hostek, 2000; Tabari and Talaei, 2011). Increasing the minimum temperature in most stations in Iran has been positively affected by global warming (Ghavidel Rahimi et al., 2017) while the maximum temperature has been less affected by global warming and its temperature trend has changed relatively less (Ghavidel Rahimi et al. 2015). Shrestha et al. (1999) by examining the changes in maximum temperature in the Himalayas and its range, for the period 1971-1994 based on maximum temperature data from 49 stations in Nepal showed that there was an increase in temperature in most stations and mountainous areas (after 1977). From 0.06 ° C to. While in the southern regions a decrease in temperature occurred (temperature increase less than 0.03 ° C). Factories located in urban areas and land use and climate change have affected temperature and its changes throughout the region. Using the least squares method and the Mann-Kendall test at 6 stations in the 60-year statistical period (1941-2000), Domroes and El-Tantawi (2005) examined recent temporal and spatial changes in Egyptian temperature and concluded that the annual and maximum temperatures Winter and autumn have been decreasing while the minimum winter and spring temperatures have been increasing. For the recent period, from 1971 to 2000, all trends except the maximum temperature were positive. Chris et al. (2007) in China, using the energy efficiency factor in building design and energy consumption, using cluster analysis method and according to solar radiation data, used the statistics of 123 stations to zoning the amount of sun and Five climatic regions were identified, the results of which were in good agreement with reality. You et al. (2010) examined climate warming in the eastern and central regions of the Tibetan Plateau in relation to climate change. They first divided the study area into 4 sub-areas in terms of temperature changes using the basis component analysis (PCA) method; They then analyzed the seasonal and monthly temperature trends for each area. Using the Mann-Kendall test and the age slope, Martinez et al. (2012) found that maximum mean temperatures in Florida, USA, increased over a statistical period of 40 years (1970-2009). El Kenawy et al. (2013) were able to divide the mountainous region of northeastern Spain into four homogeneous regions in terms of Fern temperature convergence, using the S array of principal component analysis and end clustering. Garizabal and Romero (2016) in a study entitled Homogeneous temperature series to determine the characteristics and recognition of temperature changes in the province of Santa Elena, Ecuador in the statistical period (1982-2011) showed that despite the small changes recorded in the temperature of the province, the interior is warm Wet from the beach (approximately 3 ° C) was higher in the rainy quarter than in the dry quarter. Jiang et al. (2016) in a study entitled Analysis of extreme temperature events in the Qingling Mountains and surrounding areas over a period of time (1960-2012) using 16 extreme temperature indices based on daily maximum and minimum temperature data in northern regions and south of Chingling Mountains using linear trend and correlation analysis and other methods to study the trend of temporal changes, spatial distribution pattern and correlation of extreme temperature events. The results showed that extreme cold and heat indices showed a variety of trends throughout the region. Yamato et al. (2017) in a study entitled The effect of sea breeze influence in urban areas on temperature distribution in mid-summer in Tokyo metropolitan area using observational network data (Extended-METROS) maximum temperature with case study and a combination of Temperature and wind distributions when the sea breeze showed that on all days surveyed, the areas with the highest temperatures were near Tokyo (near Kawago, 40 km from the center of Tokyo) due to a subsidence near Kawago. And the density of an amorphous hot system caused a sharp rise in temperature and the decrease in temperature in this low temperature area was relatively high. Burger et al. (2018) in a study entitled Seasonal and altitude interaction examined the temperature trends in central Chile between the years (1979-2015) in 18 temperature stations and showed that significant warming trends were widespread in domestic stations while According to previous studies, the trends in coastal places have been unusual and negative, and significant heating trends are mainly limited to spring, summer and autumn with slightly positive and negative trends in winter. Scorzini et al. (2018) in a study entitled Recent Changes in Maximum Daily Temperature in the Central Adriatic Region of Italy in the field of Mediterranean climate on an annual and seasonal basis using data from 34 meteorological stations in the statistical period (1980 to 2012) showed The increase in temperature is seen especially in spring and summer and there is a significant relationship between most of the selected indicators of maximum temperature and the pattern of the Eastern Ocean, especially for the warm season. Zhao et al. (2019) in an article entitled Earth surface temperature analysis in the central Himalayas based on MODIS sensor products in the statistical period (2007-2002) showed that the general warm environment represented by MAST on average is a distribution pattern. It has an important atmosphere with altitude gradient and also the trend test with Mann-Kendall method shows that most areas with significant changes have a growing trend and the night temperature has a significant growing trend not to the daily temperature in terms of changing areas shows. Masoudian (2005) in a study entitled "Iranian temperature trend in the last half century" Iranian monthly temperature data (night, day and day temperature) in the statistical period (from January 1951 to December 2000) with the help of monthly isotherm maps of the country with a cell size of 15% 15 and Kriging method showed that in the last half century, night, day and daytime temperatures have increased (about three, one and two degrees) per hundred years, respectively, and also showed the trend of increasing temperature in hot and low altitude areas and The trend of decreasing temperature has been seen in the mountains. Montazeri (2014) in a study entitled Spatial temporal analysis of Iranian

temperatures during the period (1961-2008) using parametric methods of linear regression and non-parametric Mann-Kendall showed that the country's temperature is increasing. This increase is more in low and low altitude areas and the trend of increasing the minimum temperature is 60% of the country's area, while the increasing trend of the maximum temperature is 27% of the country. Given that night temperature, as a time of rest, and daily temperature, as a time of activity and work, is important for urban residents. In this study, the trend of minimum and maximum temperature changes in the metropolises of Iran, which is also the largest city in each province, has been studied. The statistical period of this study was selected to include at least 33 years (three solar cycles). Comparison of temperature changes in all metropolises of Iran in a study and a long statistical period has not been done in Iran.

Significance of the study

The geographical and climatic conditions of Iran have had strong impacts on urban life, especially because of the increase in temperature, and have created issues regarding the fresh water and climate. Therefore, any increase in temperature will greatly affect both of these phenomena. Even in some metropolises, this phenomenon may turn into a climate crisis. However, Iran has a large climatic diversity due to its wide spread along latitude (28˚n to 46˚n). As a result, rising temperatures will have different effects in different climates. In this study, we investigated the changes in temperature in all metropolises of Iran throughout a long statistical period (35 years), which makes this research unique. Considering that metropolises contain more than half of the population of the country, it is essential to study temperature changes in these areas. The results of this research will provide useful information for managers for long-term metropolitan planning. Therefore, this research tries to answer the following questions:

1-Are temperature changes the same in all climates?

2-Which seasons had the highest temperature changes?

3- In which part of the day have temperature changes been the most? (maximum temperature or minimum temperature)?

4- What is the trend of temperature changes from the south to the north of Iran?

Methodology

This research is based on the following steps. In the first step, daily data of maximum and minimum temperatures of synoptic stations in the period (1985 to 2019) were received from the Meteorological Organization of Iran. In the second step, the statistical basis for the study was determined. To use the most common statistical period of Iranian metropolises, a 35-year statistical period was selected. For this reason, Sari and Yasuj metropolitan stations were removed due to the short statistical period. In the third step, the data of the selected stations were reviewed and their statistical errors were corrected by the methods accepted by the World Meteorological Organization. Figure 1 shows the location of selected metropolises on a map of Iran. In the fourth step, using the daily maximum and minimum temperature data, the average monthly temperature was prepared. In the fifth step, using the linear regression equation method, the related calculations were made using MSExcel2019 software and the Insert> scatter command, and after drawing the chart using the Add trend line command and adding options related to R ^ 2 and the line equation. Regression is obtained (dotted lines), through the regression line, and the values of the dependent variable Y can be calculated based on the values of the variable X. In the sixth step, the values of temperature changes for each of the metropolises of Iran were calculated for the two parameters of maximum and minimum temperature as follows. The values A and B were placed in the line equation. Therefore, Time was considered as an independent variable and the monthly temperature of each station was considered as a dependent variable, then the slope of the regression line was obtained.

Temperature changes for stations, in addition to the regression method, were calculated by the method of Mann-Kendall test. In the seventh step, to show the minimum and maximum temperature changes in Iranian metropolises, the calculated statistics in the GIS environment were called. Also, through the Charts index, the bar chart of the maximum and minimum temperature was performed on the Dem map and was then analyzed (Figuer1).

The results obtained from Man Kendall method were almost similar to the linear regression method, and in some cases the regression index provided more accurate results. Therefore, the results of the linear regression method were used in drawing and analyzing the maps.

Results And Discussion

Global warming is one of the most controversial topics among climatologists, politicians and even ordinary people. There are different views regrading climate change and global warming. A group of climatologists completely reject the phenomenon of global warming. Some, however, have fully accepted the phenomenon of global warming. In this study, the trend of temperature changes in Iranian metropolises has been studied over a period of 35 years without any bias from a specific perspective. Note that in the central and northern part of Iran, four seasons are quite evident. But in its southern part, four seasons are seen only in the national calendar, but in the climatic calendar, no more than two or three seasons are seen. But in this research, the analyzes have been done in four seasons.

3.1 The trend of temperature changes in Iranian metropolises in spring

Figures 3 to 4 shows 35-year temperature changes in the three months of spring.

In April, while the southern part of Iran is almost warm, in the west and northwestern regions, the weather is still cold and plants are beginning to grow and trees are to sprout. As can be seen, the temperature has increased in almost all metropolises of Iran in this month. The highest increase in maximum temperature with 2.2 ° C occurred in the city of Urmia in the northwest and Birjand in the east of Iran. In contrast, the slightest increase of 0.3 °C in the maximum temperature took place in the city of Bushehr on the Persian Gulf coast. The minimum temperature also rose in all cities of Iran (except Gorgan in

northern Iran and the cities of Ilam, Shahrekord and Shiraz in the southwest of the country). The highest elevation of 2.5 ˚C in the minimum temperature occurred in the two cities of Yazd and Zahedan, which are located on the edge of the desert. In this month, except in a few cases, in most metropolises of Iran, the temperature rose. In total, in ten metropolises, the sharpest rise in temperature was in the minimum temperature and in 17 metropolises, the highest increase was observed in the maximum temperature (Figure 3).

Figure 4shows temperature changes in Iranian metropolises in May. During this month, the southern cities of Iran enter the warm season. But, in the northernmost cities, it is the most suitable month in terms of human life and ample vegetation. In other words, it is the most suitable month for tourism in most cities of Iran except for the southern regions. In this month, the highest amount of temperature increase of 3.9 °C in the maximum temperature occurred in the city of Mashhad. Conversely, in the city of Bushehr on the south coast of Iran, the maximum temperature has decreased by about 1.3 ˚C. In other cities, the maximum temperature experience an ascending trend. The highest increase in minimum temperature of at least 3.7 °C happened in Ardabil and Mashhad, which are classified as cold-region cities of Iran. In the three cities of Ilam (tropical region), Shiraz (in the temperate region) and Shahrekord (the highest city in Iran), the minimum temperature has decreased slightly. In other cities of Iran, the minimum temperature has had a rising trend.

Figure 5shows the temperature changes in Iran's metropolises in June. This month, the southern cities of Iran experience high temperatures. However, in the western half and the northwest as well as the northeast, the temperature is still favourable and provides good conditions for human life. Also, the highest rise in temperature occurred in the maximum parameter. This increase of 3.4 ˚C occurred in Sanandaj and Ilam in the west of the country. Also in this month, the maximum temperature has decreased by 0.7˚C in the city of Bushehr in the south of Iran, which is located on the north coast of the Persian Gulf. In another metropolitan, the maximum temperatures have been increasing. In 5 cities, the increase has been higher than 3 ˚C and in 12 cities, this amount was more than 2 ˚C. The highest rate of minimum temperature increase occurred in Khorramabad. In contrast, the minimum temperature in Ilam and Shahrekord decreased by about 1.5 ˚C. In the rest of Iran's metropolises, the minimum temperature also increases. In 4 cities, this increase was more than 3 ˚C and in 8 cities it was more than 2 ˚C.

Table 1 summarizes the situation of temperature changes in each of the metropolises of Iran in the three months of spring. In April, the maximum temperature increased in 27 metropolises and showed a slight decrease in only two cities. This phenomenon has been repeated in the other two months of spring. But, for the minimum temperature parameter, there was an increasing trend in at least 22 metropolises, with five other metropolises experiencing a slight decrease. It has been unchanged in the metropolises of Tabriz and Semnan, though. For the two months of May and June, the upward trend occurred in 26 and 27 cities, respectively. Thus, in several metropolises in other metropolises of Iran, both parameters of maximum and minimum temperature have been increasing.

3.2 The trend of temperature changes in Iranian metropolises in the summer season

Figures 6 to 8 show the maximum and minimum temperature changes in Iranian metropolises in summer over a period of 35 years. In Iran, the majority of stations in July and August are the hottest months of the year. In the southern stations of the country, these two months are too hot for living and working.

In July, as the first month of summer, the highest increase in maximum temperature, at 3.6 °C, occurred in Gorgan. However, in Bushehr, the maximum temperature decreased by about 0.2 °C. In other cities, the maximum temperature experienced a rise. In 4 cities, this increase was more than 3 ˚C and in 13 cities it was higher than 2 ˚C. The highest increase in the minimum temperature parameter of at least 3.1 °C occurred in Khorramabad. In contrast, in Ilam, Shahrekord and Shiraz, the minimum temperature decreased by at least 2.7, 1.3 and 0.6 °C. But in other cities, the minimum temperature increased. In 8 cities, the minimum temperature this a increased by more than 2 ˚C (Figure 6).

In August, an increase in the highest maximum temperature occurred in the city of Ardabil (the coldest city in Iran). In this month, the maximum temperature increased by about 4.4 ˚C in the city of Ardabil. In this month, in 5 cities, the maximum temperature increased by more than 3 ˚C and in 5 cities, this increase has been higher than 2 ˚C. In contrast, in Bushehr, the maximum temperature decreased by 0.2 °C. The highest increase in the minimum temperature occurred in the city of Khorramabad at 3.7 °C. In contrast, in Shahrekord, Ilam and Shiraz, the minimum temperature decreased by 2.7, 1.9 and 1.3 °C, respectively. In 8 cities, this increase was more than 2 ˚C. The highest elevation in temperature increase in this month occurred in the northwest and northeastern regions of Iran. On the contrary, in other parts of the country, the rise has been negligible (Figure7).

In September, the highest maximum elevation in temperature of 2.8 °C occurred in Gorgan. But still in Bushehr, although slightly but, the maximum (noon) temperature decreased as much as 0.1 °C, rather slightly. In other cities except for Bushehr, the maximum temperature shows a rising trend. In this month, unlike in previous months, the increase in minimum temperature has been much greater. In this regard, the highest temperature increase of at least 3.7 ˚C occurred in Yazd. In 6 cities, this increase was more than 3 and in 6 cities it was more than 2 ˚C. However, in Ilam, the minimum temperature decreased by at least 2.6 ˚C.

Table 2shows the temperature changes of 3 months of summer. The maximum temperature increased in all the three summer months in all cities except in one. This means that the noon temperature is increasing in all metropolises of Iran. Regarding the minimum temperature parameter, in summer, the conditions are slightly different. In July, the temperature dropped in 3 of the 29 metropolitans. The metropolis of Urmia has also remained unchanged. But in other metropolises, the trend has continued to increase. In August, the number of metropolises with a minimum temperature (morning temperature) decreased to 7 cities. But still in 22 metropolises, the minimum temperature is rising. In September, in 4 metropolises, the minimum temperature decreased and in other metropolises, it increased.

3.3 The trend of temperature changes in Iranian metropolises in the autumn season

However, with the onset of autumn, temperatures in the northwest and northeastern parts of Iran drop. In the southern half of the country, the weather is still hot where human life and activity are limited. This phenomenon is quite evident, especially in October. The highest increase in maximum temperature has been seen in Zanjan. In 9 cities, the maximum temperature increase was more than 2 ˚C. Meanwhile, in Bushehr, the maximum temperature dropped by 0.3 ° C.

But in other cities, the maximum temperature rose. The increase in minimum temperature was much greater than the maximum temperature. Thus, in the city of Yazd, which is a desert and arid city, the temperature increased by at least 4 ˚C. Also, in 3 cities, the minimum temperature rose by higher than 3 and in 7 cities, the temperature was elevated by more than 2 ˚C. Meanwhile, in the city of Ilam, the minimum temperature has dropped by at least 2.4 ˚C. In the cities of Shiraz, Urmia and Shahrekord, the temperature trend, although small, constantly decreased. In this month, in general, in the arid cities of the deserts of Iran, the temperature increased more than it did in other cities (Figure 9).

In November, metropolitan temperature changes show significant differences. The first noticeable difference is in the amount of temperature change. The highest increase was 2.2 ˚C and the highest decrease was 2.3 °C. Second, in many cities, temperatures fell. In this regard, the maximum temperature in 22 metropolises plummeted. In terms of minimum temperature, in 13 metropolises, there has been a downward trend. Third, in many metropolises, both the minimum and maximum temperatures went down, and in 11 metropolises, both parameters had a falling trend, which is a strange phenomenon in Iranian metropolises (Figure 10).

There was a slightly different situation for the month of December compared to November This phenomenon is especially evident at maximum temperaturesThus, the maximum temperature continued to rise in 28 metropolises, yet rather slightly. The highest temperature increase with 3.8 ˚C occurred in Ilam station. In terms of the minimum temperature, the situation is almost the same as the previous month. Thus, in 13 metropolises, there was a downward trend in the temperature. The largest decrease occurred in Zahedan at 2.6 ˚C. However, in 16 metropolises, the minimum temperature continued to increase. The highest increase in minimum temperature, with 4.9 ˚C, occurred in Ardabil.

In Table 3, the status of temperature changes in autumn can be observed. In this season, during the first month, the conditions are the same as the previous months, with a rising trend in the maximum temperature in 28 of the 29 metropolises. In terms of the minimum temperature, the value reaches 25 cities. However, the temperature changes in the next two months are remarkably different especially in November. In this month, the maximum temperature in 22 metropolises was reduced and in three metropolises of Ahvaz, Rasht and Bandar Abbas it remained unchanged. This month, the minimum temperature increased in 16 cities and decreased in 13 others. In December, however, the maximum temperature returned to previous conditions, with 28 cities experiencing an upward trend. Despite that, in terms of the minimum temperature, in 13 metropolises the trend was still falling and in 16 metropolises it was rising.

3.4 The trend of temperature changes in Iranian metropolises in winter season

In this season, the northern half of Iran, especially in the first two months of the season, experience cold weather, yet on the south coast, there is a mild weather then. A preliminary examination of temperature changes shows that two important phenomena have occurred in temperature changes in this season. First, in almost all cities, both the maximum and minimum temperature parameters were incremental. Second, there was a significant temperature increase in most cities. Figures 12 to 14 show the temperature changes of Iranian metropolises in winter. In January, the highest temperature increase in the maximum temperature, in Zanjan, reached 5.5 degrees Celsius, which is a high figure. In 13 cities, the maximum temperature increase was more than 3 degrees Celsius and in 10 metropolises, this increase was higher than 2 degrees Celsius, which is considerable. The highest increase in temperature of at least 9.3 °C, which is noteworthy, can be seen in Ardabil. In 6 cities, the increase was larger than 3 degrees Celsius. Meanwhile, in the cities of Ilam, Shiraz and Gorgan, there was a slight reduction in the minimum temperature.

Figure 13 shows the temperature changes of February. In this month, the city of Zanjan with 5.2 degrees Celsius had the highest temperature increase in the statistical period of 35 years among the metropolises of Iran. At the same time, in 7 metropolises, the temperature increased by more than 4 ˚C, and in 4 cities, the temperature rose by more than 3 ˚C. during this month, the maximum temperature did not experience any rise in any city. As can be seen on the map, the west and northwest regions had the highest temperature rises. In total, the temperature in this region of the country increased by more than 3 ˚C at the maximum temperature. The lowest temperature rise in this month belonged to the southern and southeastern half of Iran. The highest elevation in the minimum temperature (morning temperature), still with 5.2 °C, belongs to the city of Zanjan. The cities of Ardabil, Arak and Yazd are next with 4.8, 4.2 and 4.2 ˚C, respectively. In 3 cities, an increase of greater than 3 ˚C is seen. In terms of minimum temperature parameter, the highest rise in temperature occurred in the northwestern and western parts of Iran. The southern and southeastern parts still show the least increase.

It can be observed in the March map that the highest cumulative temperature rise occurred this month. As can be seen, the highest maximum temperature increase of 6.8 °C still occurred at Zanjan station. It should be noted that in Urmia and Arak stations, the temperature increased by 6.4 and 6.3 ˚C. In 11 stations, the temperature of higher than 5 ˚C and in 9 stations, an increase of larger than 4 ˚C occurred. As can be seen, the temperature rose significantly in all cities except the southern coastal cities. The increase in the minimum temperature was the same as the maximum temperature this month when in 13 cities, the temperature increased by more than 3 ˚C. This significant increase in temperature mainly occurred in the west and northwest region and then on the shores of the Caspian Sea. This region is one of the rainiest and at the same time the most pleasant and airy regions of Iran.

Table 4 demonstrates the trend of temperature changes in Iranian metropolises during the winter months. As can be seen, in every three months of winter, the maximum temperature increased in all metropolises of Iran. The minimum temperature slightly decreased in only three metropolises in January. But in other cities, the trend was still rising. In the other two months of the winter, the minimum temperature increased in all cities.

Discussion

Global warming is a challenging issue for countries that are located in the hot and dry regions of the world and are struggling with the problem of water shortage and drought. In countries facing the problem of water shortage, drinking water supply for the urban population, especially for Metropolises, is a major problem. Most of these metropolises in hot and dry areas lack large rivers or rich groundwater resources. As a result, the increase in temperature, in addition to affecting the comfort, living and activities of human beings, but also with increasing urban water consumption (drinking, cleaning, etc.) makes the water supply of cities with serious problems. Water shortages in hot seasons may become a crisis too.

Iran has 31 metropolises, most of which are located in provincial capitals. Except for the metropolis of Ahvaz, through which a river flows, other metropolises of Iran do not have strategic rivers. The vast majority of these cities are located in large plains or foothills.

In this study, the trend of maximum and minimum temperature changes in all metropolises of Iran except Sari and Yasuj was studied in a statistical period of 35 years (1985-2019) (These two cities did not have a sufficient statistical period). The findings of the present study are as follows:

1. In the three months of spring, the three metropolises of Ilam, Shahrekord and Shiraz (which are generally located in the southern part of Iran) as well as Gorgan, which is a coastal city in the north of the country, experienced a slight decrease in temperature. In other metropolises, there was an increasing trend every three months of spring. This increase in temperature between one and a maximum of 3.9 ˚C was observed in the city of Mashhad (in the northeast of the country). Early in the season, most changes occurred in the cities of the eastern half of Iran. However, in the following months, the highest temperature increase occurred in the cities of the northern and northwestern parts. Figures 15 and 16 show the trend of temperature changes for Iranian metropolises in the 35-year period in spring. In this chart, cities are adjusted based on latitude and from low to high. As can be seen on the graphs of temperature changes, the increasing trend of temperature has intensified from the south to the north of the country. Basically, the increasing trend in the maximum temperature parameter was more homogeneous than the minimum temperature. In the two metropolises of Ilam and Shahrekord, the minimum temperature has decreased abnormally and in the metropolis of Ardabil there has been an unusual increase.

2. In summer, except for the city of Bushehr in the south, in all metropolises of Iran, the maximum temperature shows an increase. The increase in temperature in a city like Ardabil, which is one of the coldest cities in Iran, reached 4.4 ˚C. As for the minimum temperature parameter, at least in 4 metropolises, the temperature trend was falling, but in many cities, the trend was rising. The highest increase in minimum temperature reached at least 3.7˚C. Figures 16 and 17 show the trend of temperature changes in the summer months. As can be seen in the diagram, there was a sharper trend of increase, especially for the maximum temperature parameter from south to north of the country. In this season, the highest values of increase in both maximum and minimum temperature parameters occurred in the northwestern region of Iran.

3. In the first month of autumn, the temperature is almost the same as in previous seasons. In this connection, except in one city in the maximum temperature parameter and 4 cities in the minimum temperature parameter, in other cities the temperature constantly rose. Therefore, the minimum temperature in the city of Yazd increases to 4 ˚C. An important phenomenon that distinguishes this season from other seasons is that the temperature changes in the other two months of autumn, especially in November, show a significant difference with other months of the year. In many metropolises, the temperature decreased in both maximum and minimum temperature parameters. In November, the maximum temperature in 22 metropolises and the minimum temperature in 13 metropolises decreased. This is an unusual phenomenon in this month of autumn. Figures 18 and 19 demonstrate the trend of temperature changes in autumn.

4. In winter, the phenomenon of heating is serious in the metropolises of Iran. As seen on the chart, the maximum temperature rose constantly in all metropolises without exception. This phenomenon was repeated in the minimum temperature parameter except for the three cities of January. Another notable phenomenon is the amount of temperature rise. In this regard, the temperature rises to about 9.3 ˚C in a cold city like Ardabil. In other cities, increases of 4 to 6 ˚C are seen in the maximum and minimum temperatures. Figures 20 and 21 show the trend of temperature changes in winter.

Conclusion

Based on the findings, the rising trend of temperatures in Iranian metropolises is a serious issue. To answer the first research question, it was observed that temperature changes were not the same in all climates**.** An important issue is that the greatest increase in temperature occurred in the cities of the western and northwestern part of the country. As mentioned earlier, these cities have a cool climate. Most of the winter rainfall in this part of Iran is in the form of snow. Due to the climatic conditions of Iran, snow is suitable water storage for feeding groundwater aquifers. A significant increase in temperature in this part of Iran will be a matter of concern in terms of water balance because it will gradually change the type of precipitation from solid to liquid. On the other hand, snow storage at high altitudes will melt earlier than usual and will be out of reach in seasons when water is not much needed. As a result, these cities will face a serious water shortage problem in the future. In contrast, the increase in temperature in the southern regions of the country, which have a tropical climate, was very slight and sometimes decreased moderately.

The answer the second research question, temperature changes have not been the same in all seasons. The greatest increase in temperature occurred in winter. This is not a good sign for a country with an arid and semi-arid climate. Conversely, in the last two months of the fall season, especially in November, the trend of temperature changes fell in many cities. This is an unusual phenomenon, which should be investigated in a separate study.

In answer to the third question, this study showed that the values of temperature increase at maximum temperatures (noon temperature) were higher than minimum temperatures. The increase in the maximum temperature was a more stable trend in all metropolises. Therefore, the increase in temperature in Iranian metropolises became a trend. Due to the problem of water shortage in Iran and the adaptation of the cultivation period of many crops to the warm period of the year, the phenomenon of rising temperatures will greatly increase the amount of water used in agriculture and drinking.

In answering the fourth question, this study showed that the values of temperature increase from the south to the north of Iran were intensified. This increase in temperature will increase the amount of water consumed in the metropolises of the temperate and cold regions. Cities that, in the current situation, face less problems in terms of urban drinking water supply, face the problem of water shortage in the future.The results of this study are consistent with the research (Alijani et al,2011 ;Ahmadi et al,2017; Mojarrad and Basati,2018; Eblaghian, et al, 2019).

Declarations

Theoretical and Applied Climatology

Oct 05, 2021

Dear Prof. Dr. Hartmut Graßl

I would like to submit the manuscript entitled "**The trend of temperature changes in Iranian metropolises in the last three decades**" by Hassan Lashkari Nahid ghorlivand, Zainab Mohammadi,Hossein Ali Rouhbakhsh Sigaroodi to be considered for publication as an original article in the Theoretical and Applied Climatology

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

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

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

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

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Conflict of interest

The authors declare that they have no conflict of interest.

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

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

Consent to participate: 'Not applicable'

Consent for publication: we give our consent for the publication of identifiable details of the manuscript in the Natural Hazards, which could be include tables, figure and other details

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Tables

Table 1. The trend of increasing and decreasing the maximum and minimum spring temperatures of Iranian metropolises in the statistical period (1985-2019)

June				May				April				City
Minimum Temperature		Maximum Temperature		Minimum Temperature		Maximum Temperature		Minimum Temperature		Maximum Temperature		
Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	
	√		√		√		√		√		√	Tehran
	√		√		√		√		√		√	Mashhad
	√		√		√		√		√		√	Esfahan
	√		√		√		√		√		√	Karaj
	√		√	√			√	√			√	Shiraz
	√		√		√		√				√	Tabriz
	√		√		√		√		√		√	Qom
	√		√		√		√		√		√	Ahvaz
	√		√		√		√		√		√	Kermansh
	√		√		√		√	√			√	Orumiyeh
	√		√		√		√		√	√		Rasht
	√		√		√		√		√		√	Zahedan
	√		√		√		√		√		√	Hamedan
	√		√		√		√		√		√	Kerman
	√		√		√		√		√		√	Yazd
	√		√		√		√		√		√	Ardebil
	√		√		√		√		√		√	Bandarab
	√		√		√		√		√		√	Arak
	√		√		√		√		√		√	Zanjan
	√		√		√		√		√		√	Sanandaj
	√		√		√		√		√		√	Qazvin
	√		√		√		√		√		√	Khorrama
	√		√		√		√	√		√		Gorgan
	√	√			√	√			√		√	Bushehr
	√		√		√		√		√		√	Bojnurd
	√		√		√		√		√		√	Birjand
√			√	√			√	√			√	Ilam
√			√	√			√	√			√	Shahreko
	√		√		√		√				√	Semnan
2	27	1	28	3	26	1	28	5	22	2	27	Sum total
	4.6		3.4		3.7		4.8		2.5		2.2	Highest increase v celsus

Table 2. The trend of increasing and decreasing the maximum and minimum summer temperatures of Iranian metropolises in the statistical period (1985-2019)

September				August				July				City
Minimum Temperature		Maximum Temperature		Minimum Temperature		Maximum Temperature		Minimum Temperature		Maximum Temperature		
Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	
	√		√		√		√		√		√	Tehran
	√		√		√		√		√		√	Mashhad
	√		√	√			√		√		√	Esfahan
	√		√		√		√		√		√	Karaj
√			√	√			√	√			√	Shiraz
	√		√		√		√		√		√	Tabriz
	√		√		√		√		√		√	Qom
	√		√		√		√		√		√	Ahvaz
	√		√		√		√		√		√	Kermansh
	√		√		√		√				√	Orumiyeh
	√		√		√		√		√		√	Rasht
	√		√		√		√		√		√	Zahedan
	√		√		√		√		√		√	Hamedan
	√		√		√		√		√		√	Kerman
	√		√		√		√		√		√	Yazd
	√		√		√		√		√		√	Ardebil
	√		√	√			√		√		√	Bandarab
	√		√		√		√		√		√	Arak
	√		√		√		√		√		√	Zanjan
	√		√		√		√		√		√	Sanandaj
	√		√		√		√		√		√	Qazvin
	√		√		√		√		√		√	Khorrama
	√		√		√		√		√		√	Gorgan
	√	√			√	√			√	√		Bushehr
	√		√	√			√		√		√	Bojnurd
	√		√		√		√		√		√	Birjand
√			√	√			√	√			√	Ilam
√			√	√			√	√			√	Shahreko
√			√	√			√		√		√	Semnan
4	25	1	28	7	22	1	28	3	25	1	28	Sum total
	3.7		2.8		3.7		4.4		3.1		3.6	Highest increase v celsus

Table 3. The trend of increasing and decreasing the maximum and minimum Autumn temperatures of Iranian metropolises in the statistical period (1985-2019)

December				November				October				City
Minimum Temperature		Maximum Temperature		Minimum Temperature		Maximum Temperature		Minimum Temperature		Maximum Temperature		
Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	
	√		√	√		√			√		√	Tehran
	√		√		√	√			√		√	Mashhad
√			√	√		√			√		√	Esfahan
	√		√		√	√			√		√	Karaj
√			√	√		√		√			√	Shiraz
√			√	√		√			√		√	Tabriz
	√		√		√	√			√		√	Qom
	√		√		√				√		√	Ahvaz
	√		√		√	√			√		√	Kermansh
√		√		√			√	√			√	Orumiyeh
	√		√		√				√		√	Rasht
√			√		√	√			√		√	Zahedan
	√		√		√	√			√		√	Hamedan
√			√		√	√			√		√	Kerman
	√		√		√	√			√		√	Yazd
	√		√		√		√		√		√	Ardebil
√			√		√				√		√	Bandarab
	√		√	√		√			√		√	Arak
	√		√		√		√		√		√	Zanjan
	√		√		√	√			√		√	Sanandaj
	√		√	√		√			√		√	Qazvin
	√		√		√	√			√		√	Khorrama
√			√	√		√			√		√	Gorgan
	√		√		√	√			√	√		Bushehr
√			√	√		√			√		√	Bojnurd
√			√	√		√			√		√	Birjand
√			√	√			√	√			√	Ilam
√			√	√		√		√			√	Shahreko
√			√	√		√			√		√	Semnan
13	16	1	28	13	16	22	4	4	25	1	28	Sum total
	4.9		3.8		2.2		1		4		2.8	Highest increase v celsus

Table 4. The trend of increasing and decreasing the maximum and minimum Winter temperatures of Iranian metropolises in the statistical period (1985-2019)

March				February				January				City
Minimum Temperature		Maximum Temperature		Minimum Temperature		Maximum Temperature		Minimum Temperature		Maximum Temperature		
Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	
	√		√		√		√		√		√	Tehran
	√		√		√		√		√		√	Mashhad
	√		√		√		√		√		√	Esfahan
	√		√		√		√		√		√	Karaj
	√		√		√		√	√			√	Shiraz
	√		√		√		√		√		√	Tabriz
	√		√		√		√		√		√	Qom
	√		√		√		√		√		√	Ahvaz
	√		√		√		√		√		√	Kermansh
	√		√		√		√		√		√	Orumiyeh
	√		√		√		√		√		√	Rasht
	√		√		√		√		√		√	Zahedan
	√		√		√		√		√		√	Hamedan
	√		√		√		√		√		√	Kerman
	√		√		√		√		√		√	Yazd
	√		√		√		√		√		√	Ardebil
	√		√		√		√		√		√	Bandarab
	√		√		√		√		√		√	Arak
	√		√		√		√		√		√	Zanjan
	√		√		√		√		√		√	Sanandaj
	√		√		√		√		√		√	Qazvin
	√		√		√		√		√		√	Khorrama
	√		√		√		√	√			√	Gorgan
	√		√		√		√		√		√	Bushehr
	√		√		√		√		√		√	Bojnurd
	√		√		√		√		√		√	Birjand
	√		√		√		√	√			√	Ilam
√			√		√		√		√		√	Shahreko
	√		√		√		√		√		√	Semnan
1	28		29		29		29	3	26		29	Sum total
	4.8		6.8		5.2		5.2		9.3		5.5	Highest increase v celsus

Figures

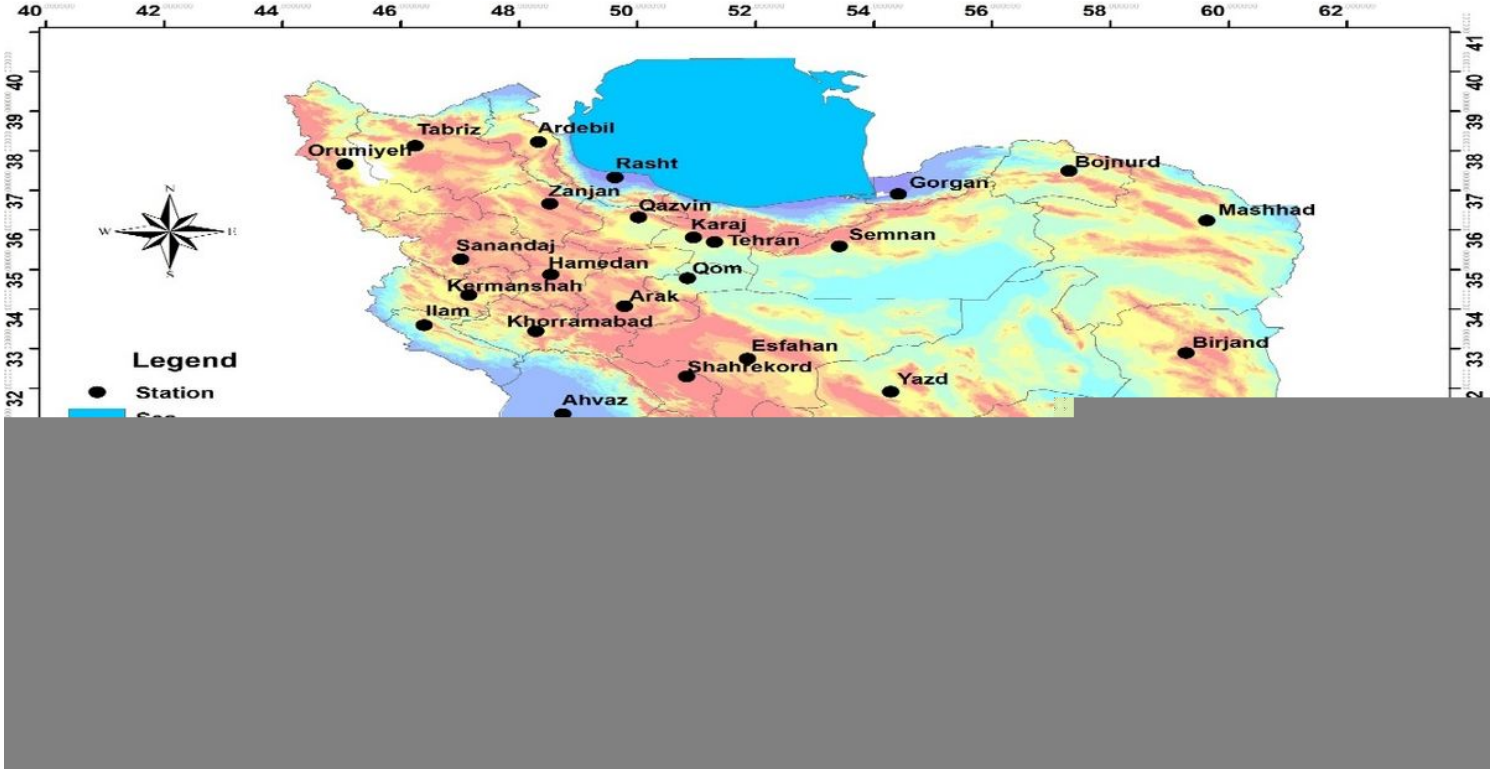

Figure 1

Geographical location of the selected metropolises in this study.

Figure 2

The minimum temperature difference of Tehran station from 1985 to 2019

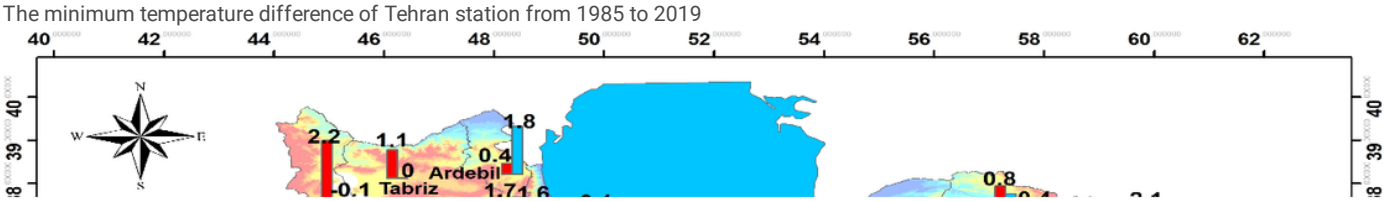

Figure 3

Long-term temperature changes (1985-2020) in Iranian metropolises - April.

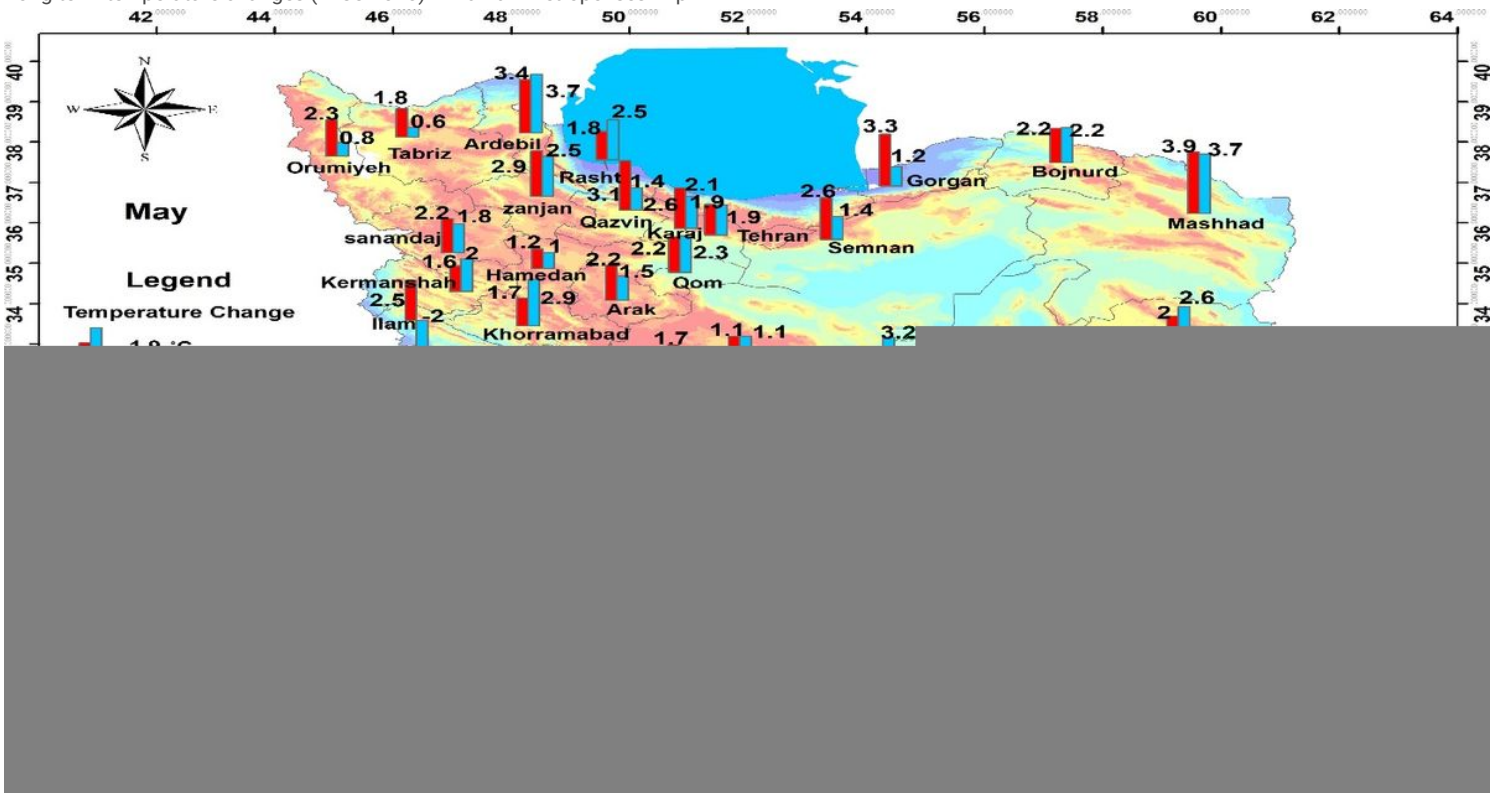

Figure 4

Long-term temperature changes (1985-2020) in Iranian metropolises - May.

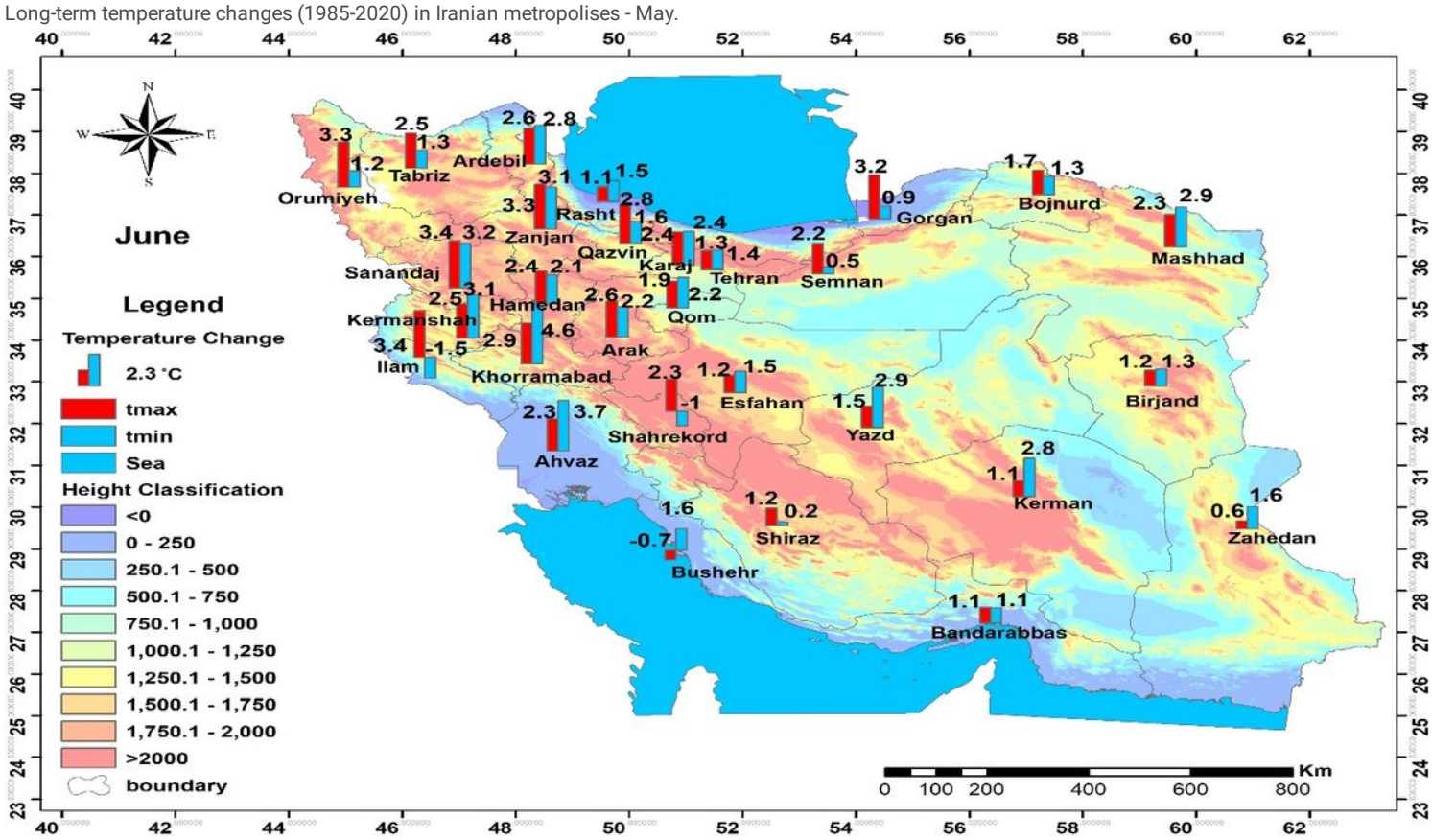

Figure 5

Long-term temperature changes (1985-2020) in Iranian metropolises - June.

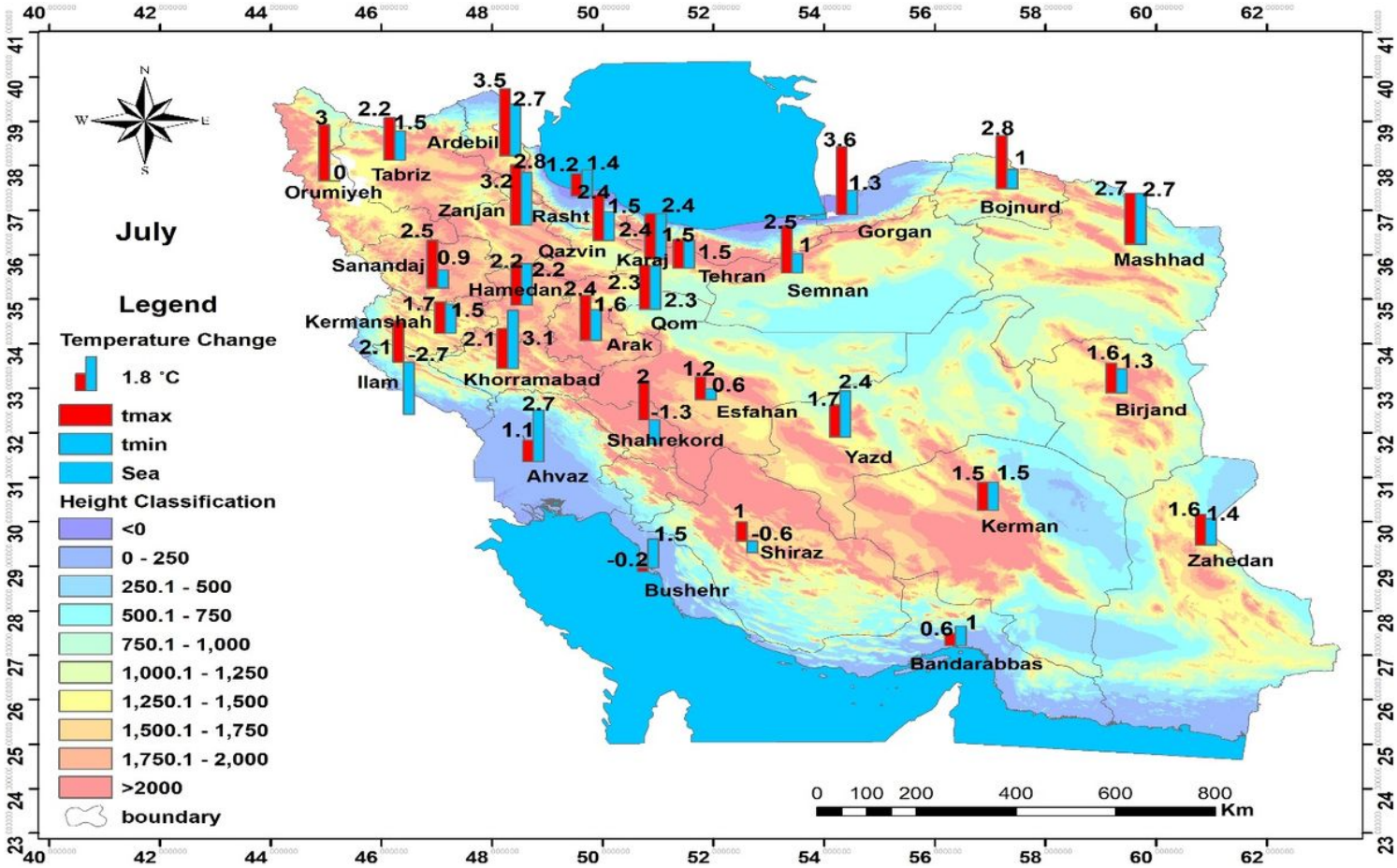

Figure 6

Long-term temperature changes (1985-2020) in Iranian metropolises - July.

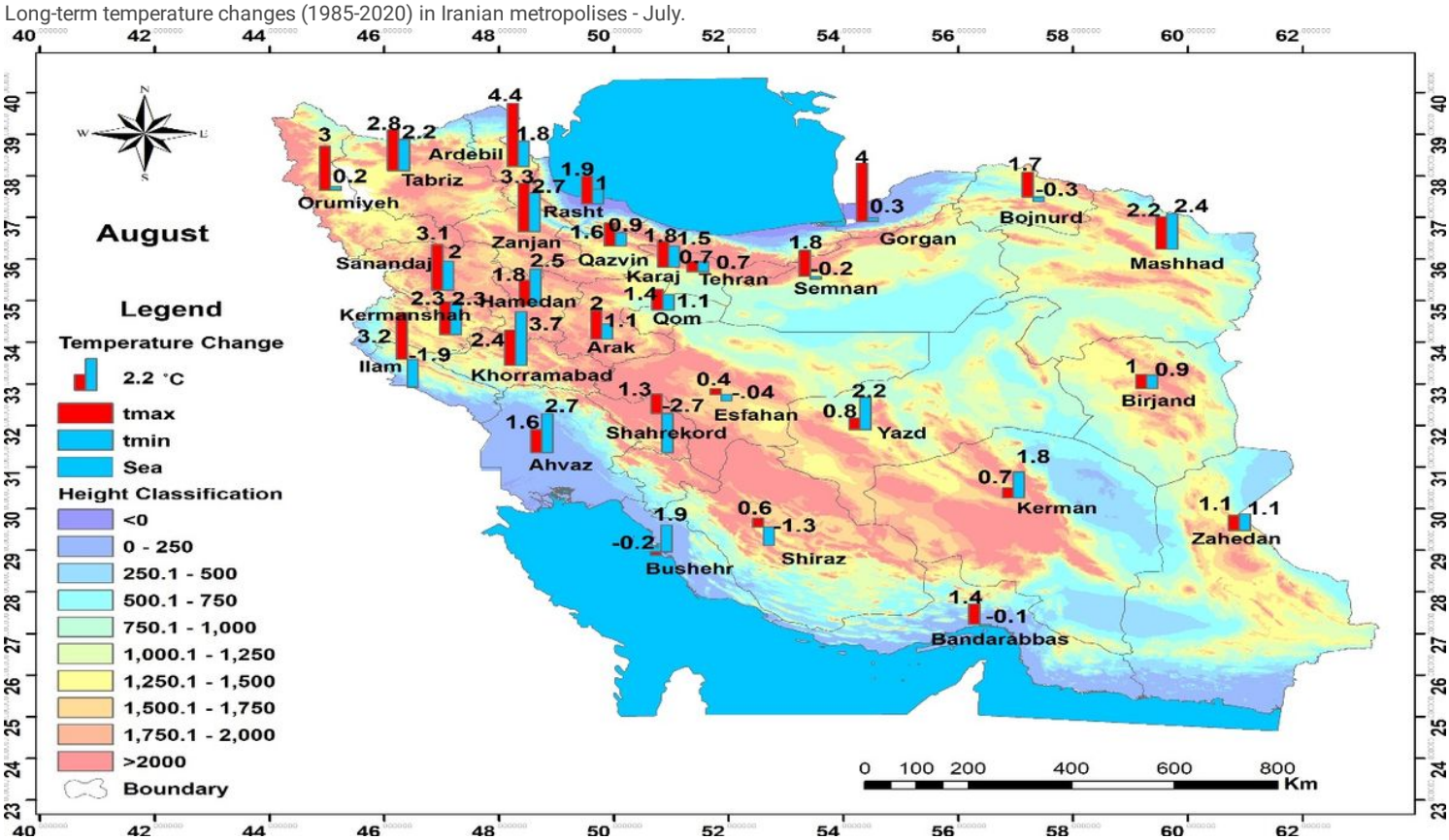

Figure 7

Long-term temperature changes (1985-2020) in Iranian metropolises -August.

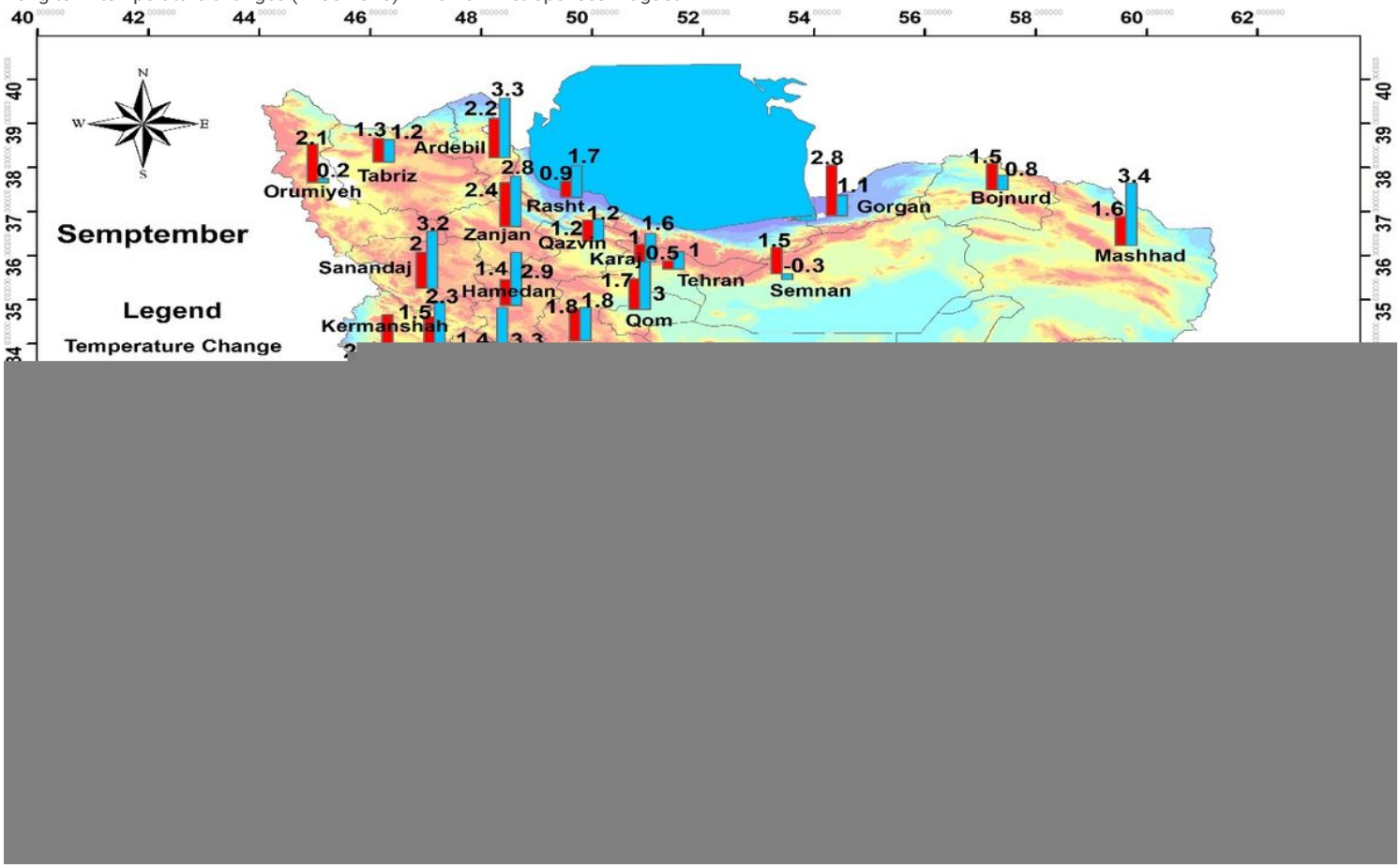

Figure 8

Long-term temperature changes (1985-2020) in Iranian metropolises - September.

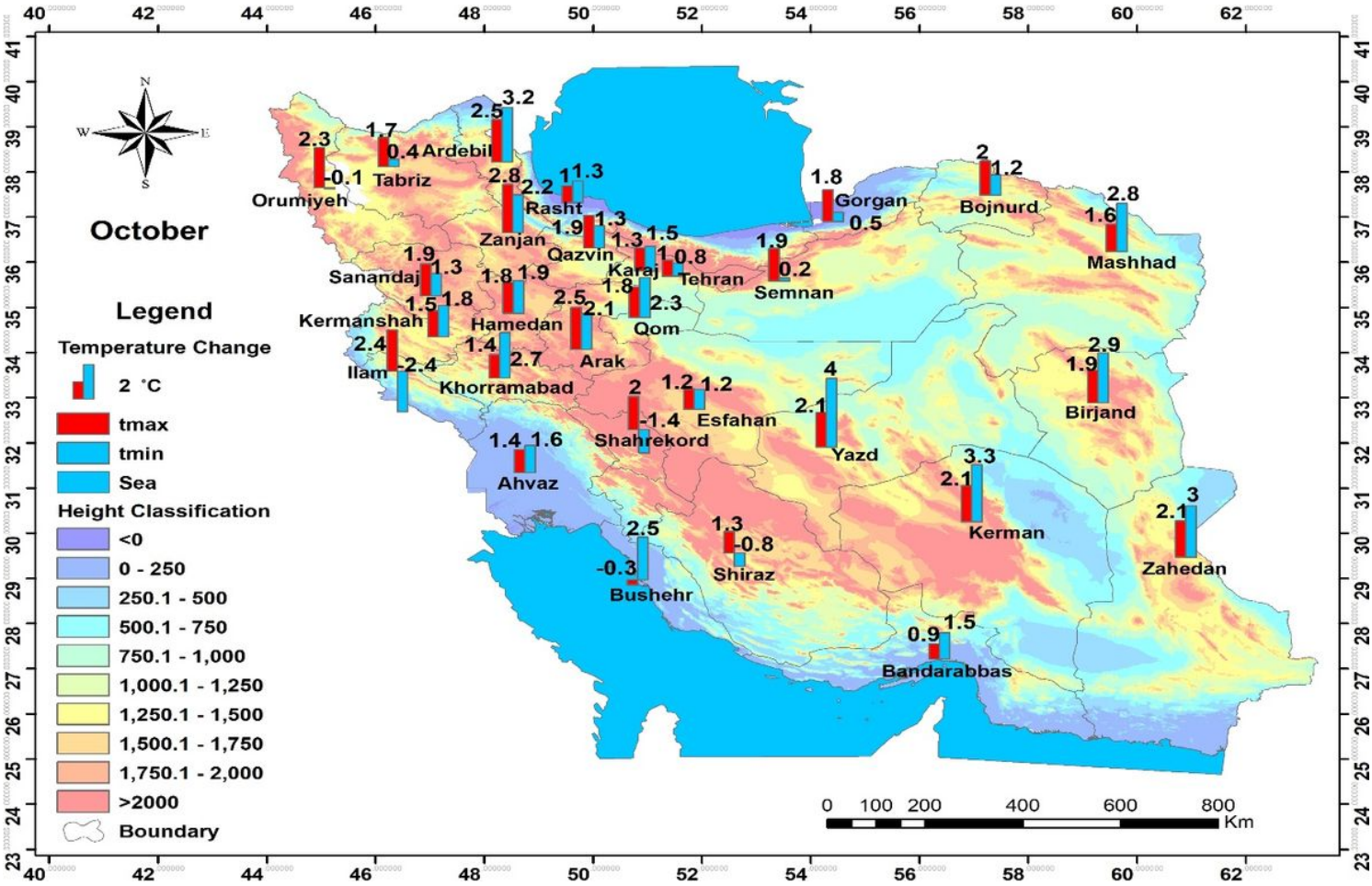

Figure 9

Long-term temperature changes (1985-2020) in Iranian metropolises - October.

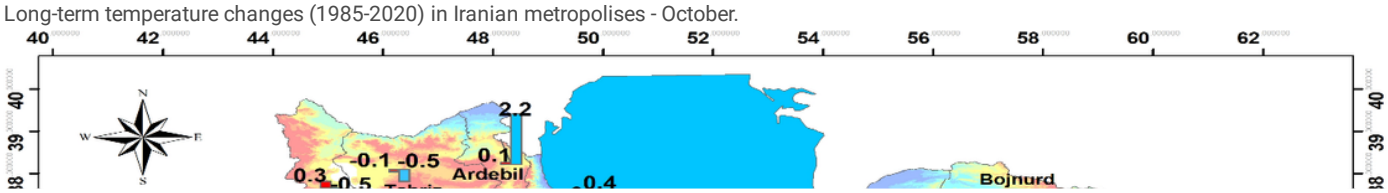

Figure 10

Long-term temperature changes (1985-2020) in Iranian metropolises - November.

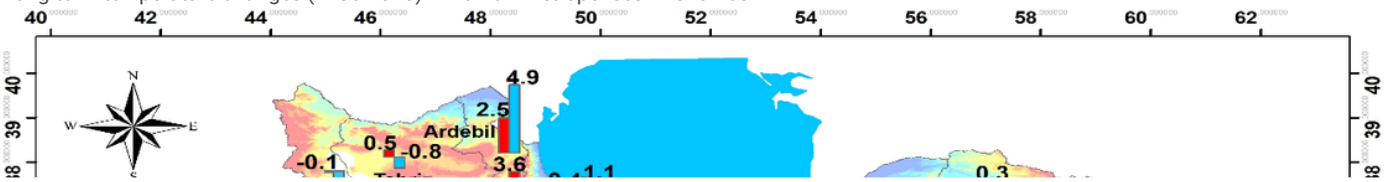

Figure 11

Long-term temperature changes (1985-2020) in Iranian metropolises - December.

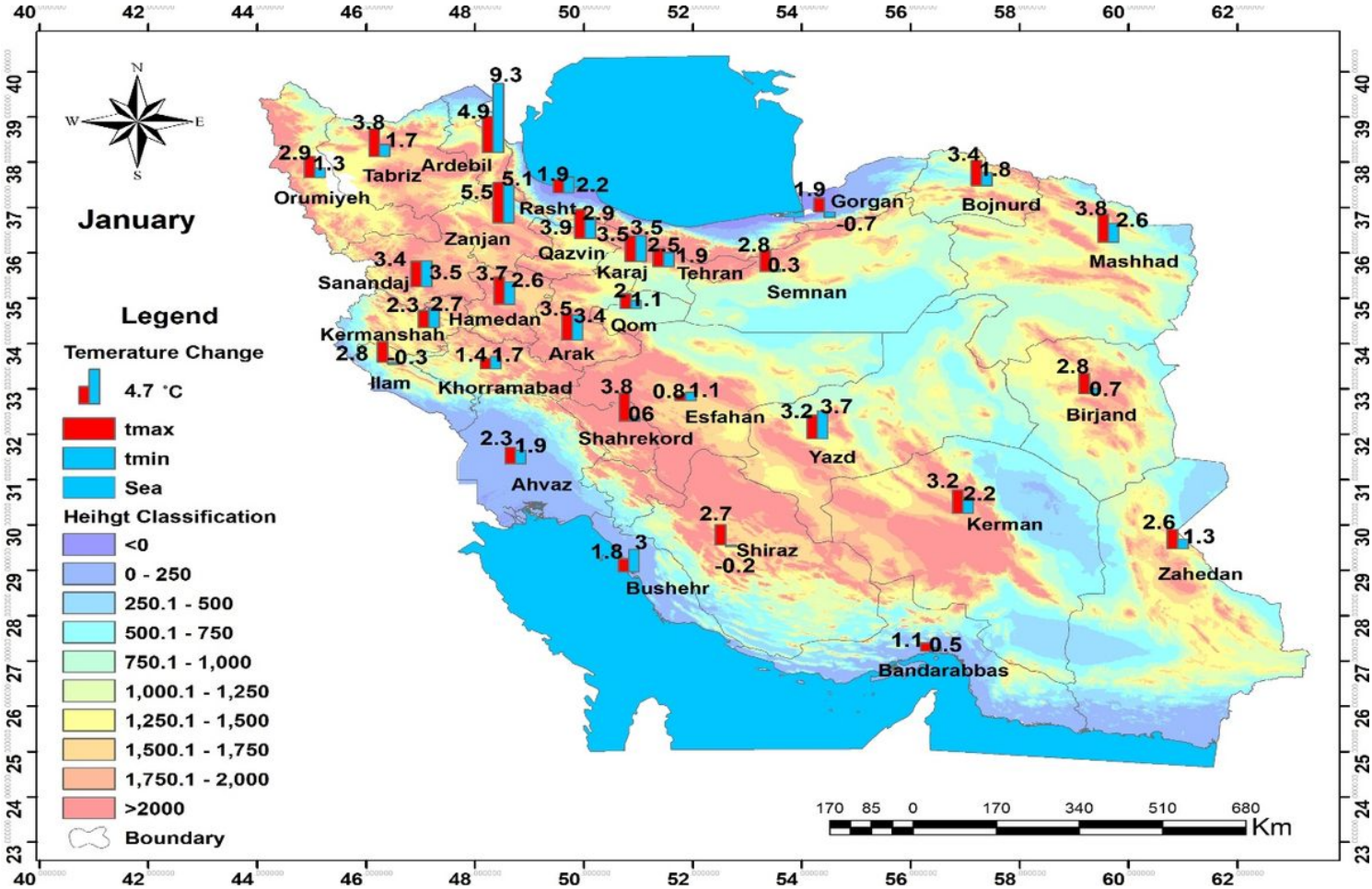

Figure 12

Long-term temperature changes (1985-2020) in Iranian metropolises - January

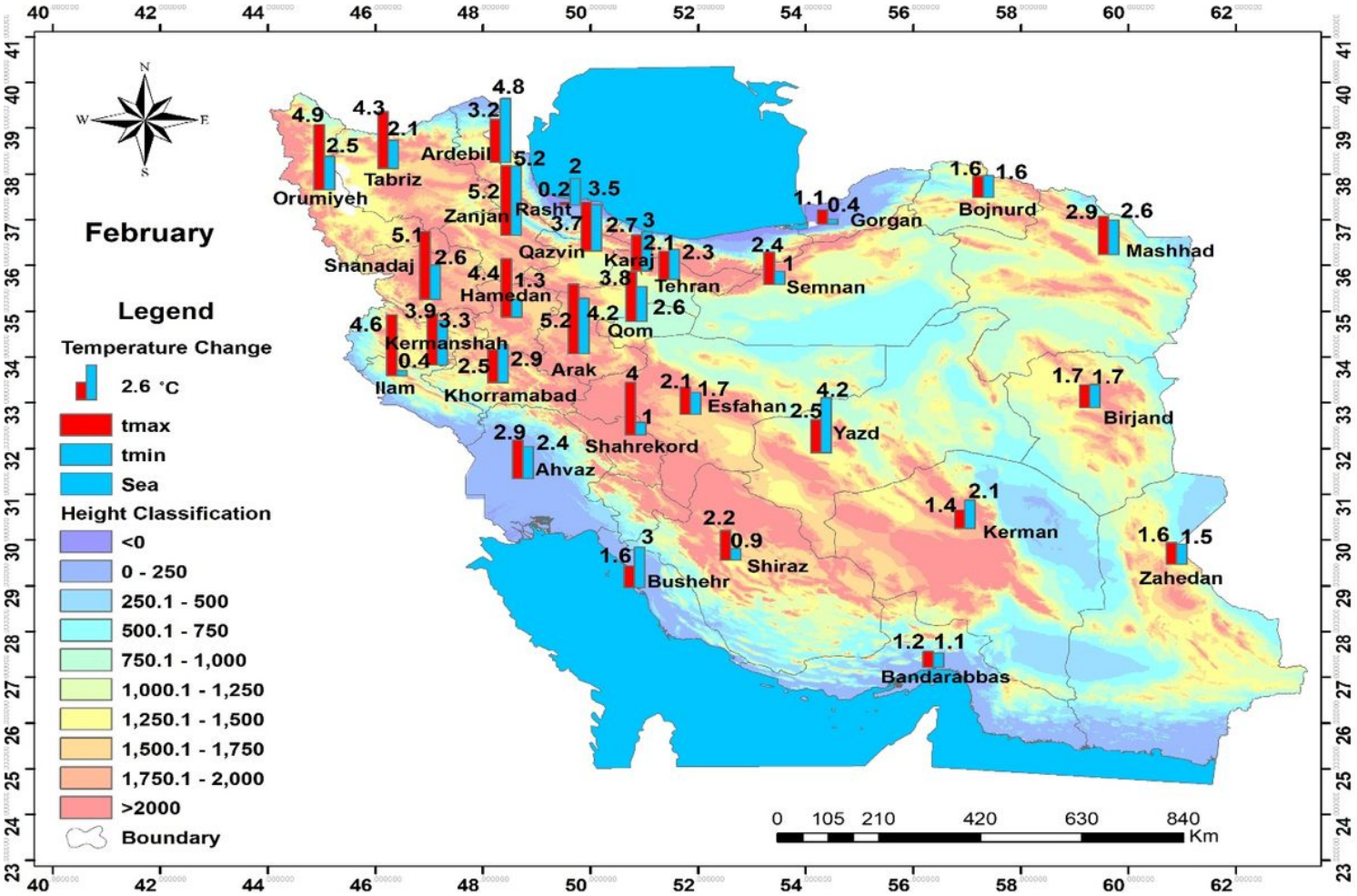

Figure 13

Long-term temperature changes (1985-2020) in Iranian metropolises -February

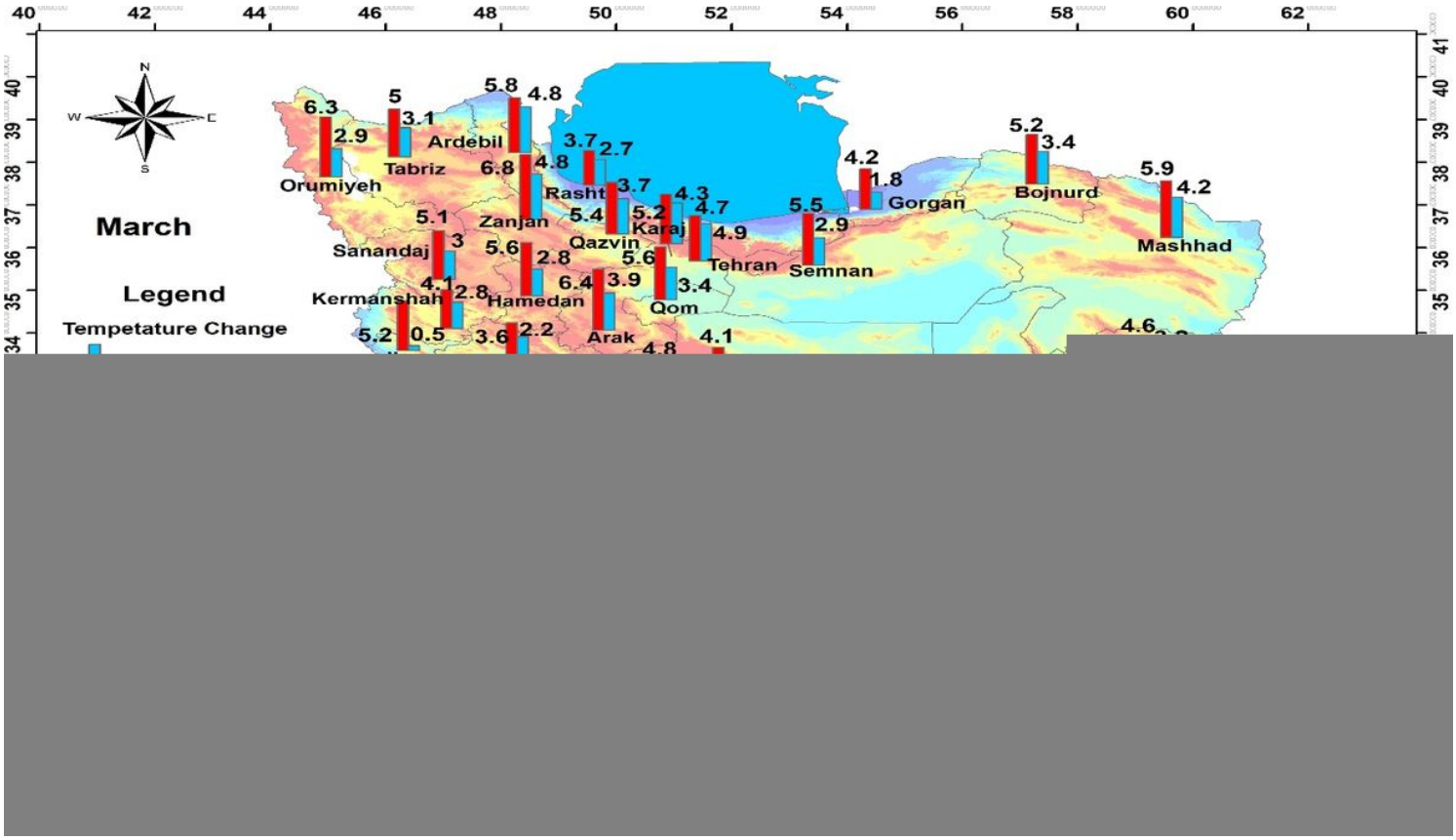

Figure 14

Long-term temperature changes (1985-2020) in Iranian metropolises – March

Figure 15

The trend of long-term changes in the maximum temperature average in the metropolises of Iran - (Statistical period 1985-2019) –spring season.

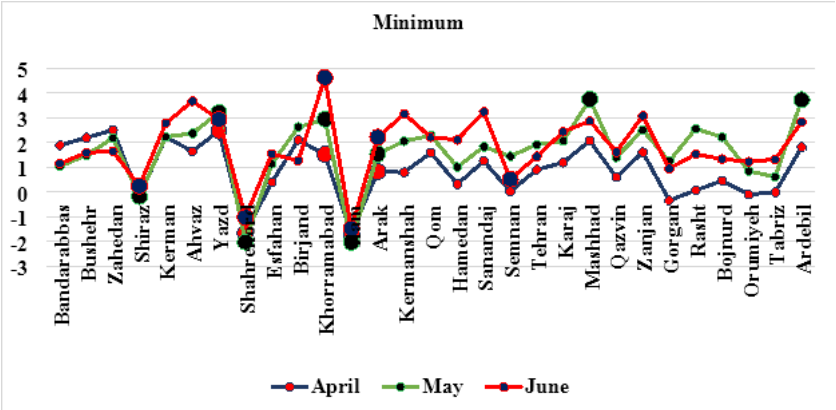

Figure 16

The trend of long-term changes in the minimum temperature average in the metropolises of Iran - (Statistical period 1985-2019) – Spring season.

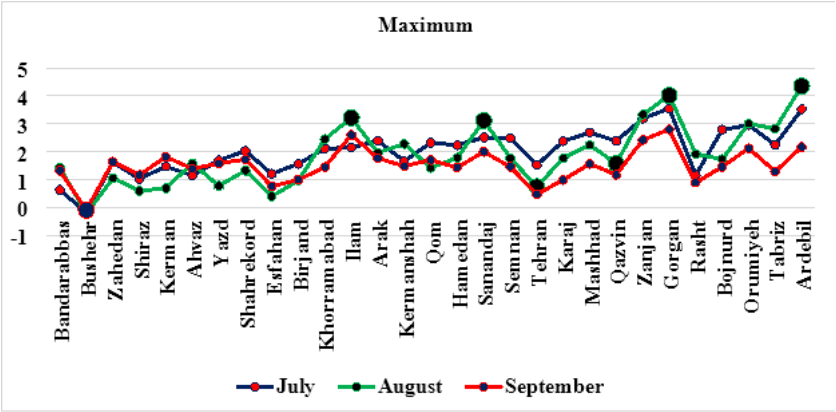

Figure 17

The trend of long-term changes in the maximum temperature average in the metropolises of Iran - (Statistical period 1985-2019) – Summer season.

Figure 18

The trend of long-term changes in the minimum temperature average in the metropolises of Iran - (Statistical period 1985-2019) – Summer season.

Figure 19

The trend of long-term changes in the maximum temperature average in the metropolises of Iran - (Statistical period 1985-2019) – autumn season.

Figure 20

The trend of long-term changes in the minimum temperature average in the metropolises of Iran - (Statistical period 1985-2019) – autumn season.

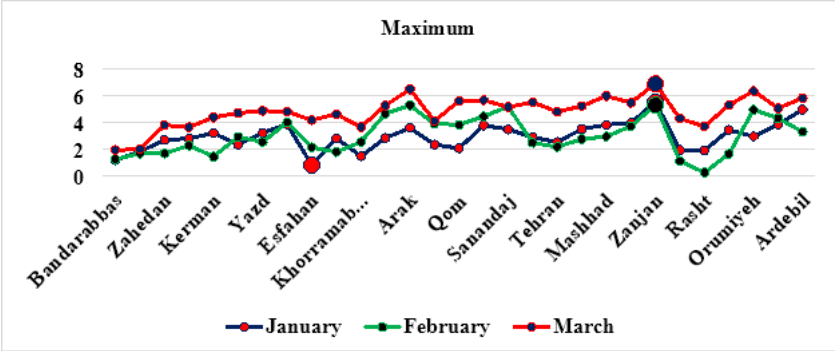

Figure 21

The trend of long-term changes in the maximum temperature average in the metropolises of Iran - (Statistical period 1985-2019) – Winter season.

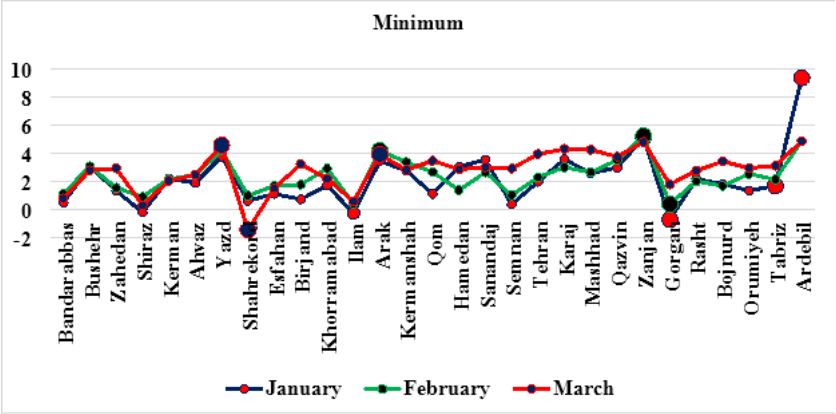

Figure 22

The trend of long-term changes in the minimum temperature average in the metropolises of Iran - (Statistical period 1985-2019) - Winter season.