CLIMATE CHARACTERISTICS OF THRACE AND OBSERVED TEMPERATURE - PRECIPITATION TRENDS

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Abstract

In this study, the main climatic characteristics in the Thrace which is Balkanian and the European part of Turkey were explained. Then the average total precipitation and average temperature and average minimum - maximum temperatures between 1975-2011 trends in the study area currently identified and explained in terms of global climate changes. In addition, long-term changes and trends in the time series of temperature and precipitation station were investigated in terms of climatic variability by using nonparametric time series analysis methods. The results obtained are summarized as follows: 1) In this study observed temperature and precipitation trends in recent years, were associated with global processes. 2) Mann-Kendall rank correlation test indicate that mean, average maximum and minimum temperatures have been generally increasing in annual average. Especially, minimum temperatures display significant increasing trends in July. 3) In the Trace meteorological stations are dominated with decreasing trend in annual precipitation amounts. Decreasing trends in precipitation totals over the study area started in the 1975 and gradually became evident during the 1990s. Kırklareli, Tekirdağ and Çorlu stations are found significant dry conditions annual precipitation series.

Keywords: *Thrace, Temperature, Precipitation, Mann-Kendall rank test.*

Introduction

Annual mean temperatures in Europe are likely to increase more than the global mean. The warming in northern Europe is likely to be largest in winter and that in the Mediterranean area largest in summer. The lowest winter temperatures are likely to increase more than average winter temperature in northern Europe, and the

highest summer temperatures are likely to increase more than average summer temperature in southern and central Europe (IPCC, 2007).

Annual precipitation is very likely to increase in most of northern Europe and decrease in most of the Mediterranean area. In central Europe, precipitation is likely to increase in winter but decrease in summer. Extremes of daily precipitation are very likely to increase in northern Europe. The annual number of precipitation days is very likely to decrease in the Mediterranean area. The risk of summer drought is likely to increase in central Europe and in the Mediterranean area (IPCC, 2007).

Kadıoğlu (1997) used the seasonal Mann-Kendall test to detect temperature trends across Turkey and observed that there was a tendency for a warming trend over the period 1939–89, in contrast to a tendency for a cooling trend lasting from 1955 to 1989. However, these implied temperature trends were not statistically significant. Karaca et al. (1995) applied the Mann–Kendall test and the method of linear regression to the monthly mean temperatures to detect the urban heat-island effects in Istanbul, which is the largest metropolis in Turkey. They found positive trends for southern stations and negative trends for northern stations, reflecting the importance of densely populated districts in Istanbul.

Partal and Kahya (2006) studied long term trends in Turkish precipitation data, especially in January, February, and September precipitations and in the annual means. They found a noticeable decrease in the annual mean precipitation was observed mostly in western and southern Turkey, as well as along the coasts of the Black Sea.

Study area comprises the Thrace which is Balkanian and the European part of Turkey. Thrace is the name given to the region located in the southeastern part of the Balkans. According to the records of ancient Greece the borders of this region is determined in north by the Danube River, in south by the Aegean Sea, in west by the east of the mountains of the Vardar River, and in east by the Black Sea, the Bosphorus and the Marmara Sea.

Thrace can be identified as a low-field plateau. However, Edirne Tekirdağ-Silivri line located roughly on NW - SE axis extending Thrace create a view lower than the overall average, relatively high masses surround Thrace in N and S (Yıldız Mountains max. 1031m and Ganos Mount max. 924 m) directions.

Today, however, it is the region including the eastern part of Bulgaria's southern Aegean Sea, Greece, with a section extending to the territory of Turkey into the European continent. However, in this study the region of Thrace, which is only in the territory of Turkey, is considered.

The annual and January, July temperature trends of mean, maximum and minimum air temperature are analyzed by Mann-Kendall rank test in the last decade. The study focuses on the trends of the annual, January and July mean, maximum and minimum temperatures, and precipitation.

Data and Method

In this study, the mean, minimum and maximum temperature series of 6 meteorological stations for the period 1975-2011 were used provided by The Turkish State Meteorological Service (TSMS). Properties of the stations are given in Table 1.

Table 1: Characteristics of the meteorology stations in Thrace used in the study.

Met. Stations	Code Num	Altitude	Latitude	Longitute	Data (Years)
Edirne	17050	51	416767	265508	37
Kırklareli	17052	232	417382	272178	37
Tekirdağ	17056	4	409585	274965	37
Kireçburnu	17061	59	411464	290502	37
Kumköy	17059	38	412505	290384	37
Çorlu	17054	183	411557	278173	37

The non-parametric Mann-Kendall (M-K) rank correlation test is used to detect any trend in air temperature and precipitation series (Sneyers, 1990). The Applying the *M–K* test, the original observations of x_i are replaced by their corresponding ranks *ki*, such that each term is assigned a number ranging from 1 to N reflecting its magnitude relative to the magnitudes of all other terms. Then, for each element k_i, the number n_i of elements k_j preceding it (i > j) is calculated with ($k_i > k_j$): The value of the first term of the series k_1 is compared with the values of all latter terms in the series from 2nd to Nth; number of the latter terms whose values exceed k_1 is counted up, and then this number is denoted as n_1. Then, value of the 2nd term k_2 is compared with the values of all the latter terms; number of latter terms that exceed k_2 is counted and it is denoted as n_2. This procedure is continued for each term of the series. The following equation is defined total of n_i's,

$$t = \sum_{i=1}^{n} ni \qquad (1)$$

The distribution function of *t* is assumed to be asymptotically Gaussian with the mean (expectation) and variance as,

$$E(t) = \frac{n(n-1)}{4} \qquad (2)$$

and

$$\mathrm{var}(t) = \frac{n(n-1)(2n+5)}{72} \quad (3)$$

respectively. In two-sided test, the null hypothesis of absence of any trend was rejected for large values of u(t).

$$u(t) = \left[t - E(t)\right] / \sqrt{\mathrm{var}(t)} \quad (4)$$

Long-time trend and significant change point is determined by *M-K* rank correlation test. *u*(*t*) values display direction of trend in the time-series plots of the *u*(*t*) and *u*'(*t*).

General Topographic Features of Thrace

Thrace, as an extension of the territory of Turkey into the Balkans and Europe, covers an area of approximately 3% of Turkey's surface area. In terms of surface area of Thrace, although different sources state that it has an area of 23-24000 km2, according to a study carried out by Kurter et al. (1985). The map with a scale of 1:25,000 in 214 km region, the surface area used is 23.588.8km^2 (Kurter et al., 1985).

According to the same study distribution on the steps of elevation between the 0-250m 82.7%, 250-500m between the 14.1%, 500-1000m between the 3.2% are observed in Thrace. The only point of Thrace with 1000 m of height is Yıldız Mountains Ridge Hill (1031 m) this single point does not have an effect to change the overall percentage. The steps of altitude distribution of Thrace are reflected to the average elevation of the region and the average altitude of the area is calculated as 159m (Kurter et al., 1985).

Thrace considered in terms of topographic features can be expressed in 4 basic sections (Ardel, 1955). These are; **1.** North and North East Yıldız Mountains, **2.** Ergene basin in the middle section, **3.** South Korudağ - Ganos Mountain, **4.** Marmara Coast.

Topographically, the differences in the distribution are in conformity with the range of climatic elements and their differences set forth in the district. In other words, the distribution of rainfall and temperature, particularly within the region, including the distribution of climatic elements, are very consistent with the above topographic features.

Overview of the main lines of this topography is effective on creating natural life as well as the characteristics of climatic elements revealed. Although, especially the distributions of temperature and precipitation characteristics of topography are effective, the main risk factors on natural habitats and agriculture are the

distribution of rainfall and rainfall per year. For this reason, studies on climatic elements of Thrace have been made on rain and the distribution of rainfall.

Looking at today's natural appearance of Thrace, as also expressed by Dönmez, it is mainly characterized as "anthropogenic steppe" pitches in and around the central Ergene basin, and as the dry forest area in N and S regions.

This appearance is changing from day to day as a result of anthropogenic pressures and natural areas are being degraded. When we observe the climatic conditions, which are the main cause of natural appearance, we can also observe the surface shapes and the steps of the surface elevation of intra-regional differences. However, before proceeding to the climatic characteristics of the regions directed by factors of physical geography, the location and the overall climate conditions in Thrace should be evaluated in terms of the general atmospheric circulation.

General Atmospheric Cırculatıon in Thrace

Turkey and Thrace, being in the middle latitudes, are also positioned in mid-latitudinal temperate climate area. On the other hand, being on the east of the Mediterranean Sea, Thrace is affected by the macro climatic features of the Mediterranean.

Middle latitudes are in the impact area of the seasonal cycles, depending on the movement of the Polar Front and Inter tropical Convergence Zone, north polar (P) and from the south Tropical (T) air masses. These masses create the most important planetary fronts of the troposphere when they meet in these latitudes. These great oscillations of discontinued surface prevent the field to be dominated by a certain mass of air all year round. In this regard, both Turkey and Thrace area both in the transition area by means dynamic air-conditioning.

Air masses that affect the scope of the study can be divided into two sections in terms of seasons or periods that they are effective in. First of all, when we consider the cold period by dynamic point of view (winter season, between October to April), the study area and even the entire Mediterranean basin and its surroundings take the form of an active frontojenez area. These air currents coming from different directions meeting on the ellipse of the Mediterranean basin form strong discontinuities. This discontinuity surface area also forms an effective convergence area. Thus, a significant cyclonic environment is formed on the basin.

During the cold period on the Black Sea and in particular in its eastern area, a small scale of secondary converging area is formed. The main reason for this is the thermal differences occurring between the Black Sea being located as in an inland sea and the continental land masses around it.

Cyclonic weather conditions that characterize the period of the cold, frontal rains and ensuing hot and cold circuits are formed in this way. This is particularly evident in coastal sections.

Another important issue between the cyclonic activities and significant relations between Turkey's climatic features is created by the moving depressions. The most interesting feature of these moving depressions in terms of the route that they follow is: they come close to Turkey in terms of west, and then divide into two, the first passing through the straits in the Black Sea and along the coasts to east moving towards north, another part is that moving in the direction of the south Anatolia, along the shores of the Gulf of Iskenderun. It is obvious that Turkey's topographical features are effective on this layout movement. The reason for receiving more rainfall in the cold period for the coastal part of Turkey is the moving low-pressure structures.

In the warm period, the cold polar air masses that affect Turkey and Trace are pulled towards north, i.e. the pole. In this case, the tropical air masses in south are pulled to towards higher latitudes. Current terms and conditions for the warm period are shaped in west by the advancement of the Azores High Pressure center towards north, and in south by the correct insertion of ITCZ depending on particular thermal reasons. As a result of this, the general frontoliz conditions are effective in the Mediterranean basin and Turkey. Therefore, during the summer, high temperatures, low rainfall, generally clear skies, plenty of good weather cumulus and NW-N and NE winds form the climatic characters.

These seasonal conditions that result from the general atmospheric circulation feature two different climate characteristics in Thrace during the year. In this context, we can roughly talk about two main periods: cold and warm periods. Under this general structure, Thrace's local conditions may vary depending on the conditions explained as in this topography. These local topographical features affect rainfall and rainfall distribution in particular and also affect temperature distributions differences in certain ways.

Precipitation Distribution over Thrace

In terms of the distribution of precipitation, low rainfall areas are along the Ergene basin, roughly corresponding along NW - SE region. Rainfall in this area is about 500-600 mm. However, high areas in the north and south of this line take more rainfall. In the north, precipitation is around 800 mm to up the Yıldız Mountains, while the mountains in the south, around the Ganos take 700-800 mm (Figure 1).

The distribution of precipitation is affected by the Iceland low-pressure coming from over the Aegean Sea and moisture-laden air masses coming from its facade systems.

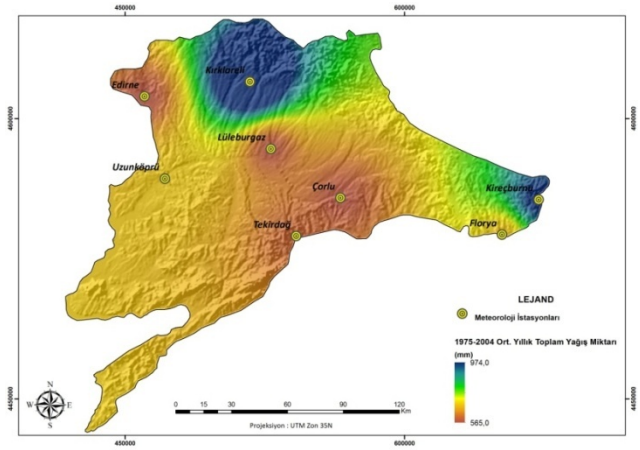


Figure 1: Distribution of Annual Average Total Precipitation in Thrace (1975-2004).

Also, the mobile depressions taking the moisture introduced by north Black Sea into the field, is another reason for high rainfall for the northern parts in the cold period. Therefore, when we consider the seasonality of precipitation in the field, i.e. the rainfall regime, we can analyze that the major significant amount of rainfall takes place between the months October to April which we call the cold period.

Summer precipitation in the east and south of the field stations is around 14-15%. According to these rates, the distribution of seasonal rainfall is somewhat between the Aegean, the Mediterranean and the Black Sea characteristics. In other words, the precipitation of the field is in between the Black Sea and the Mediterranean rainfall characteristics. However, as generally seen in Turkey, the field also has significant differences in rainfall measures throughout the cold period-the hot period. The total precipitation of cold period (October-April) varies between 57-58% and it is 65% in the Marmara coast (Tekirdağ) area. This is, as stated above, due to a feature brought by the cyclone areas and facade systems connected to it that affect the mid-latitudes in cold periods like Turkey.

However, terrestrial and maritime features can be explained distribution of precipitation over the field by the terms. In a study conducted in order to compare Edirne and Tekirdağ, it has been understood that Edirne has more terrestrial features than Tekirdağ in terms of the distribution of precipitation (Gönençgil 1997). Although the average annual total precipitation of these two places are not different from each other, (Edirne 579.34 mm-Tekirdağ 584.41 mm) the difference btw their terrestrial and maritime features can be explained in regards to the development of conditions of evaporation.

In another study, Thrace is categorized to be in medium wet areas of Turkey when considered in terms of rainfall intensity and amount (Erlat, 2000). In this study when we analyze the distribution classification of rainfall intensity as per rainy days per year classes the rainfall under 10 mm make up the 80% of precipitation.

However, it will not be wrong to express that the increase in amount of rainfall and increasing incidence of flooding are due to major settlements in the region along with unplanned urbanization and environmental degradations.

Temperature Distribution over Thrace

When we look at the average annual temperature values of the distribution in Thrace, we can see that it is around 13-14^{o}C. Indeed, according to the data btw 1975-2009, in Edirne, the value of the average annual temperature was 13.6^{o}C in Kırklareli 13.1^{o}C, 13.9^{o}C in east Tekirdağ and Kireçburnu appeared to be 13.7^{o}C (Figure 2).

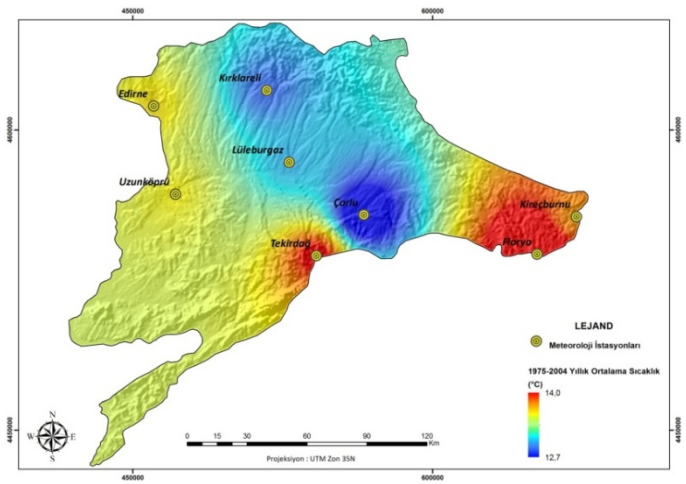


Figure 2: Distribution of Annual Average Temperatures in Thrace (1975- 2009).

Periods of the cold and hot average temperatures (between January and July) reveal the terrestrial and maritime features of the area. Especially in cold period, representing average January temperature was 2.7^{o}C in Edirne, Kırklareli was 3.1^{o}C, 5.0^{o}C in Tekirdağ and Kireçburnu 5.6^{o}C, respectively. The difference in winter temperatures between these coastal and inland cities has not been reflected in the average July temperature. In the field, average temperature of Kireçburnu is 22.7^{o}C in July and 24.6^{o}C in Edirne, respectively. Although the difference of 2^{o}C is not considered too high to be seen in a short distance, it can be perceived as a reflection of the terrestrial and maritime feature of the area.

According to the distribution of the average maximum temperature, same temperature characteristics display in around Marmara Sea coastal. Lüleburgaz station has very high temperature values in average maximum temperature. Edirne, Lüleburgaz and Uzunköprü stations have obviously terrestrial climate. Kırklareli

such as Lüleburgaz is located to inland, but it has a maritime climate with regard to temperature characteristics (Figure 3).

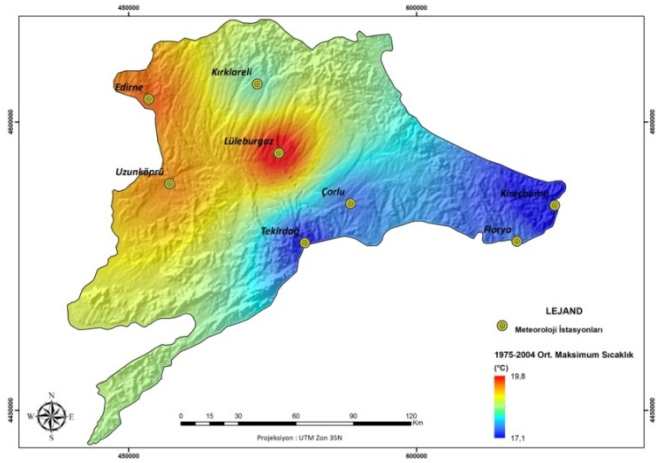


Figure 3: Distribution of Average Maximum Temperatures in Thrace (1975- 2004).

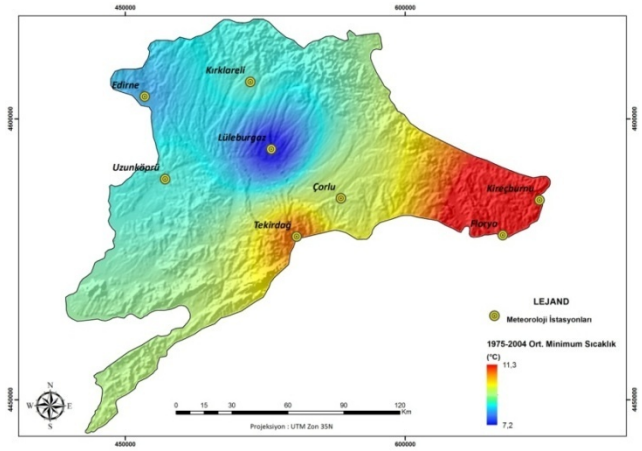


Figure 4: Distribution of Average Minimum Temperatures in Thrace (1975 – 2004).

Kireçburnu and Florya meteorological stations have a same temperature characteristic by annual minimum temperatures. Lüleburgaz and Edirne stations are very low temperature values in the period of 1975-2004. Temperature values are lower than coastal, temperature characteristics of Edirne and Lüleburgaz stations are obviously terrestrial climate in annual minimum temperature. Uzunköprü and Kırklareli stations have similar temperatures values like this Kireçburnu and Florya, but this stations temperature values lower than coastal area (Figure 4). It is clearly

possible to see traces of continentalite in average maximum and average minimum temperatures in terms of values.

General Climate Characteristics of Thrace

Thrace is under the influence of climate types characterized by its geographical location and the basic characteristics of physical geography as well as marine and terrestrial conditions.

The coastal regions of Thrace surrounded by the Aegean, Marmara and Black Sea are under the influence of marine environment in different degrees of severity whereas the inland of Thrace is under the influence of inland continental climate characteristics.

The distribution of temperature and precipitation features explained above also support this fact. Coastal areas are relatively warm-temperate in the summer whereas the continental inland is hot in the summer, and the winter is cold in the inland and temperate through coastal areas. These general climatic characteristics have effects on human activities as well as nature and environment.

Observed Temperature and Precipitation Trends in Thrace

Mean Air Temperature

Mean air temperature represents statistically significant positive (increasing) trend in July and yearly. Trends are not significant in all of stations in January. The slightly increasing trends display over the stations in January and the significant warming is seen over the all of the stations in July and annual mean temperature (Table 2).

Table 2: Resultant test statistics and their significance levels from Mann-Kendall test for mean temperature values in Thrace meteorological stations.

Stations	January		July		Annual	
	u(*t*)	*Sig.*	*u*(*t*)	*Sig.*	*u*(*t*)	*Sig.*
Edirne	0.37	0.71	3.51**	0.001	3.24**	0.001
Kırklareli	0.89	0.37	3.44**	0.001	2.22*	0.03
Tekirdağ	0.41	0.68	4.66**	0.0001	3.48**	0.001
Kireçburnu	0.60	0.55	4.20**	0.0001	3.13**	0.002

Kumköy	0.22	0.83	3.94**	0.0001	3.15**	0.002
Çorlu	0.72	0.47	3.75**	0.0001	2.51*	0.01

(*) Significant at 0.05 level and (**) 0.01 level.

Mean air temperature displays insignificant increasing trend. Monthly mean temperatures were also warmer than long-term average since 2000 in January. All of the stations have statistically significant an increasing trend in July mean temperatures and stations have increasing trend after change point in the late 1990s. Mean temperatures of these stations have dominated significant increasing trends since the early 2000s in July. Stronger warming trends of July mean temperatures are mostly observed all of the stations (Figure 5).

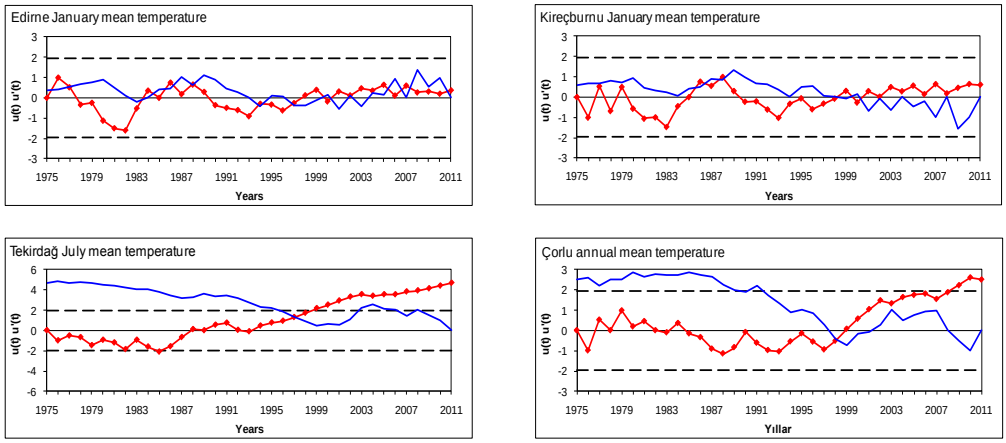


Figure 5: Long-term trends of mean temperature values in January and July selected stations in Thrace according to the Mann–Kendall rank correlation test by $u(t)$ (—●—) and $u'(t)$ (——)values.(——),±1.96 critical value displays at the 0.05 level of significance in normal distribution.

Minimum Air Temperature

Mann-Kendall rank correlation test indicate that minimum temperatures have been generally increasing in annual and July. Trends are not significant in all of stations in January (Table 3).

Table 3: As in Table2, but for minimum temperature.

Stations	January		July		Annual	
	u(*t*)	*Sig.*	*u*(*t*)	*Sig.*	*u*(*t*)	*Sig.*
Edirne	0.01	0.99	2.14*	0.03	1.83	0.07
Kırklareli	-0.64	0.52	2.66**	0.01	1.41	0.16
Tekirdağ	-0.16	0.87	3.41**	0.001	3.09**	0.002
Kireçburnu	0.59	0.56	2.21*	0.03	2.64**	0.01
Kumköy	0.13	0.90	3.77**	0.0001	3.81**	0.0001
Çorlu	0.03	0.98	3.14**	0.0001	2.14*	0.03

(*) Significant at 0.05 level and (**) 0.01 level.

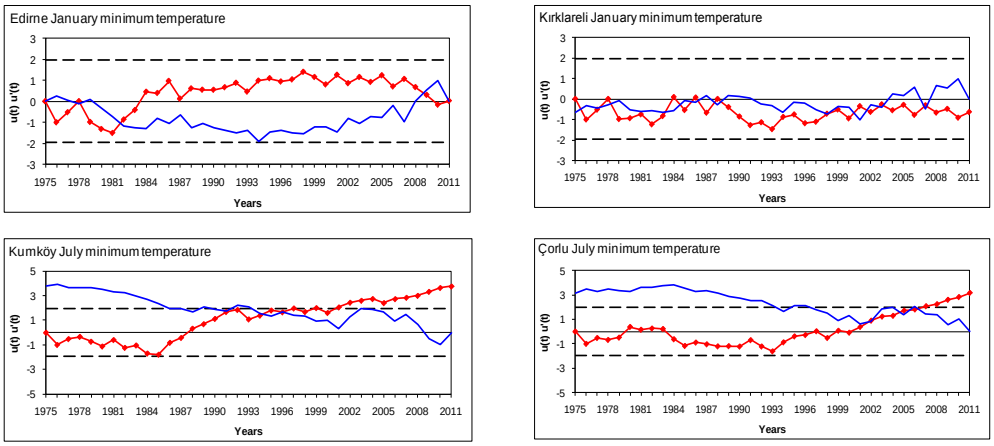


Figure 6: As in Figure 5, but for minimum temperature.

In general minimum air temperatures are increase trends after the early 2000s. Spatial and temporal patterns of trends in minimum temperatures are very similar to those of mean temperatures. Trends in all of series are not significant in January. A general cooling is dominant in Kırklareli and Tekirdağ stations, whereas a general warming is seen over the other stations. Edirne and Kireçburnu are at the significant level of 0.05, whereas the other stations are significant level of 0.01 in July. Long-time trends are clear in all of the stations since the early 1990s in July (Figure 6).

Maximum Air Temperature

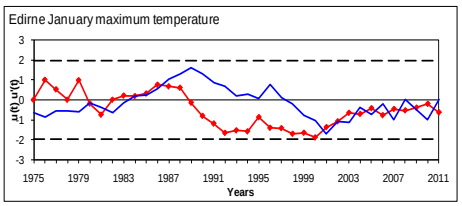
The annual maximum temperatures are significant in all stations. July maximum temperatures show a general increasing trend over all of stations, whereas a general cooling is seen over the Edirne stations (Table 4).

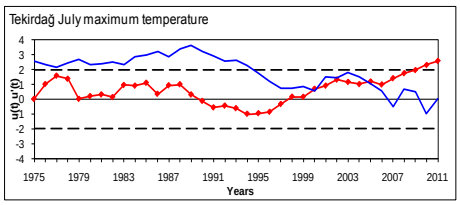
Table 4: As in Table2, but for maximum temperature.

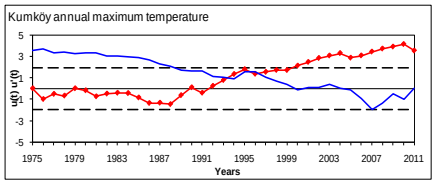
Stations	January		July		Annual	
	u(*t*)	*Sig*.	*u*(*t*)	*Sig*.	*u*(*t*)	*Sig*.
Edirne	-0.64	0.52	0.93	0.35	2.62**	0.01
Kırklareli	1.12	0.26	1.70	0.09	3.27**	0.001
Tekirdağ	0.64	0.52	2.56*	0.01	3.91**	0.0001
Kireçburnu	0.94	0.35	1.49	0.14	2.69**	0.01
Kumköy	1.26	0.21	1.67	0.10	3.52**	0.0001
Çorlu	0.55	0.58	0.69	0.49	2.41*	0.02

(*) Significant at 0.05 level and (**) 0.01 level.

Edirne has an insignificant increase trend in annual maximum temperature after the 1998 change points and a significant warm period is 2007-2010. Kırklareli and Tekirdağ stations have a statistically significant increasing trend in annual temperature since 1992, 1994, respectively. Kireçburnu, Kumköy and Çorlu stations display a long-time significant increasing trend since 2000s (Figure 7).







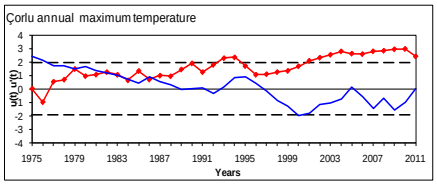


Figure 7: As in Figure 5, but maximum temperature.

Edirne January maximum temperature series display a decreasing trend since the early of 1990s. The other stations have an insignificant increasing trend since 2000s July maximum temperatures have displayed an insignificant increasing trend in Edirne, Kireçburnu, Kumköy and Çorlu station since late of 1990s. An insignificant increasing trend is clear in Kırklareli July maximum temperature since the 1980s.

Precipitation

The total annual precipitation is observed decreasing trend in all of the stations except Edirne and Kireçburnu. Edirne station, observed a decreasing trend since 1975, has changed the direction of an increasing trend since the early 1990s.

Table 5: As in Table2, but for precipitation.

Stations	January		July		Annual	
	u(*t*)	*Sig*.	*u*(*t*)	*Sig*.	*u*(*t*)	*Sig*.
Edirne	0.67	0.50	2.02*	0.04	0.53	0.60
Kırklareli	-0.18	0.86	1.33	0.18	-0.47	0.64
Tekirdağ	-1.15	0.25	-0.94	0.35	-0.14	0.89
Kireçburnu	-0.84	0.40	-1.33	0.18	0.89	0.37
Çorlu	-1.41	0.16	-0.97	0.33	-0.36	0.72

(*) Significant at 0.05 level and (**) 0.01 level.

Kırklareli precipitation series display a decreasing trend since 1975. 1986, 1988-1997 and 2001 years are significant dry periods in Kırklareli station. Tekirdağ

station also includes a decreasing trend in precipitation but this series have a weak increasing trend since the mid-1990s. 1992-93 years are significant dry period in Tekirdağ station. Kireçburnu station is observed a decreasing trend 1970s but this trend is changed as an increasing trend in the late 1990s. Çorlu precipitation series display a decreasing trend since 1975. 1989-1990 and 1992-94 years are a significant dry period in Çorlu station. January precipitation series are similar to the total annual precipitation trends. July precipitation series display increasing trends in Edirne, Kırklareli stations whereas Tekirdağ, Kireçburnu and Çorlu stations observe decreasing trends in particularly after the 1990s (Figure 8).

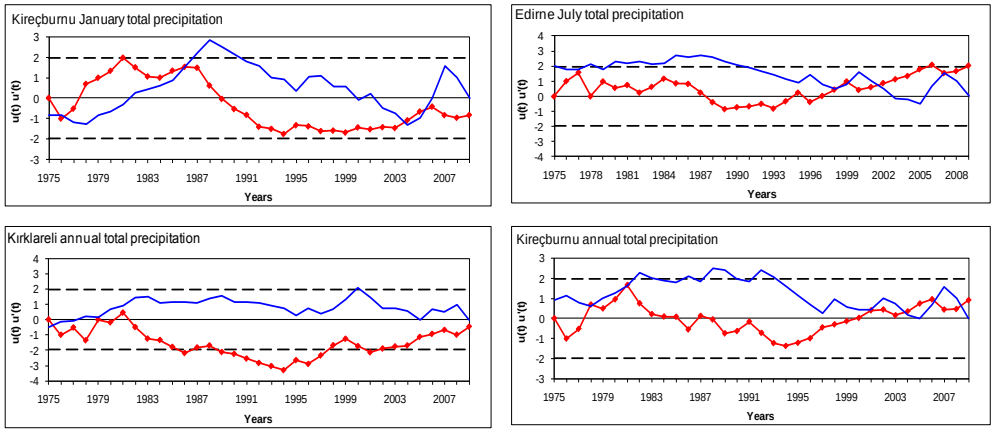


Figure 8: As in Figure 5, but precipitation.

Results

Thrace has two different types of climatic characteristics. One of them is continental inlands, other maritime coastlines. Rainfall changes year by year is important risks for natural life and agriculture. Heavy rains sometimes can be reason of natural disasters. But main problem is civilization and urbanization.

Global Climate Changes especially affected the Mediterranean area. Thrace has undercondition main Mediterranean Climate. People should find adaptation ways to these new conditions.

At some stations, the beginning point of the warming is found in the late 1970s and 1990s. Significant warming begins immediately after the early 1990s and the early 2000s.

Mean air temperature displays significant increasing trend in July and annual all of the stations. Especially, mean temperatures were also warmer than long-term average since 2000. Minimum air temperature shows increasing trends after the early 2000s. July minimum temperature indicates long-term increasing trends all of

the stations. Maximum temperature also displays significant increasing trend. Increasing trends have obviously been mean and minimum air temperature.

Results of the Mann-Kendall test have pointed to decreasing trends in the Thrace. But some years and stations have more precipitation than the long term averages. July precipitation series display increasing trends in Edirne (significant) and Kırklareli stations, whereas Tekirdağ, Kireçburnu and Çorlu stations observe decreasing trends in particularly after the 1990s.

In Thrace's annual precipitation series are found significant dry conditions during the period 1989-1997 in Kırklareli, during the period of 1992-1993 in Tekirdağ, during the periods of 1989-1990 and 1992-1994 in Çorlu, respectively.

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