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Statistical Evaluation of Predicted Maximum and Minimum Temperatures with CLIGEN Climate Model

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Abstract: Climate simulation models are widely used in generating estimated daily data to be used in climate change, soil erosion, water holding capacity, water quality, product development, and many other studies. Climate models are used to simulate the impact of future climate smülations in cases when long-term measured data is not sufficient, the measured data contain erroneous records since the collection of observed data is costly or requires a lot of time. Most climate models predict one or more climate variables such as wind speed, relative humidity, solar radiation, temperature, and precipitation. Climate models such as the CLIGEN, USCLIMATE and the WXGEN create max and min temperature values using the standard normal distribution. In the present study, the CLIGEN climate model was used to simulate the long-term average temperature data for Kayseri, Sivas, and Yozgat meteorologic stations. The compliance of both observed and simulated data with the normal distribution was determined by the Kolmogorov-Smirnov test. It was observed that the maximum and minimum temperature values did not conform to the normal distribution, and the skew value was negative for almost all months. It was found that the CLIGEN simulated above the observed value for the summer months and the values obtained for some months showed the normal distribution.

Keyword: CLIGEN, Climate, Kolmogorov-Smirnov, Simulation, Temperature.

CLIGEN İklim Modeli ile Tahmin Edilen Maksimum ve Minimum Sıcaklıkların İstatistiksel Değerlendirilmesi

Öz: İklim simülasyon modelleri iklimsel değişiklikler, toprak erozyonu, su tutma kapasitesi, su kalitesi, ürün gelişimi ve benzeri birçok çalışmada kullanılmak üzere tahmini günlük verilerinin oluşturulmasında yaygın olarak kullanılmaktadır. Gelecekteki iklim senaryolarının etkisini simüle etmek için, uzun süreli ölçülen veriler yeterli olmadığında, ölçülen veriler hatalı kayıtlar içerdiğinde, gözlenen verilerin toplanması maliyetli ya da çok zaman gerektirdiği için iklim modelleri kullanılmaktadır. İklim modellerinin çoğu rüzgar hızı, bağıl nem, solar radyasyon, sıcaklık ve yağış gibi bir ya da daha fazla iklim değişkenini tahmin etmektedir. CLIGEN, USCLIMATE ve WGEN gibi iklim modelleri, standart normal dağılım kullanarak mak ve min sıcaklık değerleri oluşturmaktadır. Bu çalışmada Kayseri, Sivas ve Yozgat meteorolojik istasyonlarına ait uzun yıllar ortalama sıcaklık verileri CLIGEN iklim modeli ile simüle edilmiştir. Hem gözlenen hem de simüle edilen verilerin normal dağılıma uyumu Kolmogorv-Smirnov testi ile belirlenmiştir. Aylık gözlenen maksimum ve minumum sıcaklıkların normal dağılıma uymadığı, çarpıklık değerinin hemen hemen tüm aylar için negatif olduğu görülmüştür. CLIGEN, yaz ayları için gözlenen değerin üzerinde simüle ettiği ve bazı aylar için bulunan değerlerin normal dağılım gösterdiği görülmüştür.

Anahtar Kelmeler: CLIGEN, İklim, Kolmogorov-Smirnov, Simülasyon, Sıcaklık

1. Introduction

The performance of solar energy system changes based on wind velocity,ambient temperature and clamminess. These factors are identified according to their change over time (Lenderink and Meijgaard, 2010). Air temperature is expressed as the amount of moisture retained in the atmosphere (Martinkova and Hanel, 2016). Individual precipitation events and increases in precipitation intensity happen based on the increases in temperature (Lenderink and Mejgaard, 2010).

Surface air temperature is one of the most important factors for climate change (Romily, 2005). Global climate change indicators are used to indicate the change of surface temperature over time.These are; (1) positive recycling between ambient temperature and carbon cycle (Chapin III et al., 2009), and (2) earth temperature which control soil air and soil failure (Bindraban, 2012), cause and effect between global warming and decreasing bio-diversity (Mayhew et al., 2008), the changes in plant phenology (Kaushal et al., 2016) and growing season.

Temperature is an important parameter in many environmental factors (Ye et al., 2008). Generally, climate change smülations use the average of temperature over a certain period of time. In the general directorate of meteorology, temperature data of past 150 years read automatically with digital tools. These tools evaluates actuarially temperature (Hansel et al, 2006). Although the daily maximum and minimum temperature data show normal distribution, they do not show a normal distribution due to many factors. Data shows distribution below or above the observed data but they are moving away from normal.

The method used to evaluate the daily maximum and minimum temperature data is very important. Because, the temperature values found as a result of the simulation must be close to the observed temperature values. Therefore, the climate model must be suitable for the climatic conditions of the area (Kumar et al., 2011). There are many studies on the changes in daily temperature values due to climate change during the 20th century and at the present time. In these works, the effects of temperature changes on agriculture, forestry, environment and human comfort were evaluated with climate model. Most widely used climate models are the WGEN (Richardson, 1981; Richardson, 1984), USCLIMATE (Hanson et al., 1994), CLIGEN (Nicks et al., 1995), CLIMGEN (Stockle, 2001), LARS-WG (Semenov, 2002).

The CLIGEN climate model is widely used all over the world. However these the studies on climate models are not very common in Turkey. Demir (2016) simulated long years precipitation data of Tokat region through the CLIGEN climate model. The CLIGEN climate model was reported to be suitable for the climatic conditions of the region. Demir et al. (2020) conducted a drought analysis in Tokat province using the precipitation simulated with the CLIGEN. According to the preliminary research, there is no study on the trend of long-term temperature data simulated with the CLIGEN climate model in Turkey and the effects of these on agricultural production. In this study, in which the Standard Rainfall Index was used, it was reported that there is always a risk of drought above medium severity. The present study aims to 1) simulate the observed data with the climate model, 2) evaluate the performance of the model by analyzing the conformity to normal distribution of both observed and simulated data.

2. Material and Methods

In the study, maximum and minimum temperature data for Sivas, Yozgat and Kayseri provinces having the Central Anatolia Transition climate type were used (Figure 1).

Table 1 presents general information about the stations. The Central Anatolia climate type is among the coldest climate types. The average temperature is -5.1 ˚ C in January, 18.6 in July, and 7.3 annually (Table 2). The average annual precipitation is 447 mm and most of the precipitation occurs in spring. The proportion of the summer precipitation within the annual total is 13%, the average annual relative humidity is around 64%. In this climate type, daily insolation times are up to 1.4-3.1 in winter and 10.1-11.2 in summer (Table 2). These three provinces differ in winter season. Winters are colder in Sivas and rainier in Yozgat than the other two. April and May are the wettest months in all three provinces, the July-September period is dry and there is a drought risk all year round. Data from the meteorological stations between 1967 and 2018 were simulated with the

CLIGEN climate model. The Kolmogorov-Smirnov (KS) test was used to perform the conformity to normal distribution analysis for both observed and simulated temperature data.

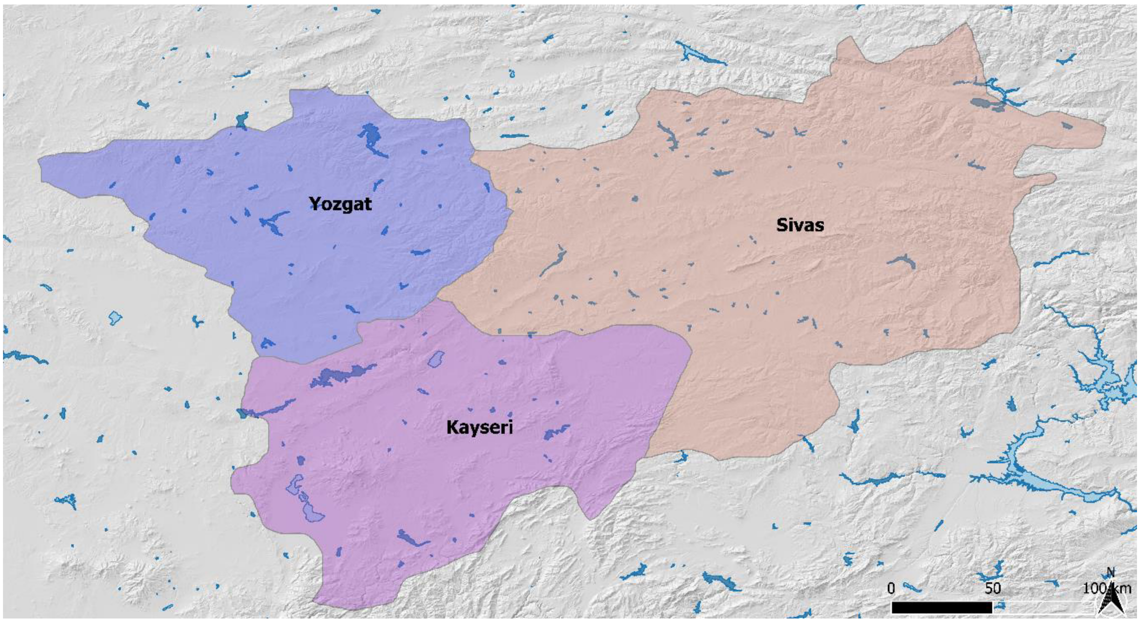


Figure 1. The location of the study area
Şekil 1. *Çalışma alanı*

Table 1. The general features of the study area
Çizelge 1. *Çalışma alanının genel özellikleri*

Regionals	Stations Name	Latitude °	Longitude °	Mean Year Rainfall (mm)
The Central	Sivas	39.74	37.02	445
Anatolian Eastern	Yozgat	39.82	34.82	592
Transitional Climate	Kayseri	38.73	35.48	380

Table 2. Monthly distributions of climate variables belonging to the study area
Çizelge 2*. Çalışma alanının iklim değişkenlerinin aylık dağılımı*

Climate Variable	Months												Yıllık ortalama (mm)
	1	2	3	4	5	6	7	8	9	10	11	12	
Max. Temp. (°C)	-0,4	0,9	6,1	13,4	18,1	22,5	26,8	27,1	23,3	16,5	8,5	2,0	13.73
Min. Temp. (°C)	-9,7	-8,9	-4,5	1,5	5,0	7,7	10,5	10,2	6,3	2,3	-2,6	-6,8	0.92
Ave.Temp. (°C)	-5,1	-4,0	0,8	7,4	11,6	15,1	18,6	18,7	14,8	9,4	3,0	-2,4	7.32
Precipitation (mm)	37	36	46	64	67	37	13	8	15	40	41	43	37.25
Relative Humidity (%)	75	73	69	64	63	58	54	53	54	63	71	76	64.42

2.2 Method

2.2.1. Meteorological Data

The daily max and min air temperature values between January 1, 1967 and December 31, 2018 were used. First, the normality of temperature data was evaluated graphically. Seasonal frequency analysis and goodness of fit curves were obtained for each station. The expected frequency curve (in determining the standard deviation and average distribution of the observed data) was plotted on each histogram.

Values obtained from the normal distribution were used to describe the possible deviation. The skewness coefficient of each area was calculated to provide the other numerical criterion and to evaluate the seasonal deviation of the normal distribution. The skewness coefficient is 0 a symmetrical normal distribution.

The mean and standard deviations of the monthly data observed were used in the simulation of climate data with the CLIGEN (52 years). It is very important to compare the observed and predicted data. The simulation data obtained are taken as a reference in the selection of crops to be grown in the future, in agricultural activities such as tillage, and in planning hydraulic structures such as soil and water conservation.

2.2.2. The Kolmogorov–Smirnov (KS) test

The KS test derives the distance between the empirical cumulative distribution function (ECDF) of the observed time series and the cumulative distribution function (CDF) of the candidate distribution (Corder and Foreman, 2009; Salarpour et al., 2012; Sharma and Ojha, 2019). The KS test statistic (Dn) for a given candidate cumulative distribution function [F(x)] is the largest vertical difference between F(x) and Fn(x). The equation for the KS test statistic (Dn) and the ECDF are defined in 3. Here, supx is the least upper bound of the set of distances and IXi#x is an indicator function, which is 1 if Xi # x or 0 if otherwise. If this greater than the critical value (here 0.198) at the 0.05 significance level, the hypothesis on the distributional form is rejected (Tale 3).

Table 3.Functions of goodness-of-fit tests
Çizelge 3. *Uyum iyiliği testleri*

Test Name	Abbreviation	Procedure	Functions for test statistics
Kolmogorov–Smirnov	KS	Proximity analysis of the empirical distribution function (obtained on the sample) and the hypothesized distribution (theoretical)	$K-S=\sup\left\|F_n(X)-F_0(X)\right\|$

2.2.3. Stochastic Climate Generator (CLIGEN)

CLIGEN is a climate model that simulates climatic parameters such as precipitation, maximum and minimum temperature, solar radiation, relative humidity, wind direction and intensity. It makes daily meteorologic data forecasts using the Markow Chain, which predicts the probability of a wet day P (W/W) following a wet day and a dry day P (W/D) following a wet day. The simulations use the amount of precipitation on a wet day and the skewed normal distribution. (Nicks and Gander, 1994).The predicted air temperature with the CLIGEN may be higher than the temperature of the dry day following a dry day, and may be lower than the temperature of the wet day following a wet day. (Nicks and Harp, 1980; Richardson, 1981). The WEPP model estimates the temperature using the equation given below:

Tmax = Tmx + (STmx)*(v)*(B) (1)

Tmin = Tmn + (STmn)*(v)*(B) (2)

Here; Tmax and Tmin are the simulated maximum and minimum temperatures. Tmx and Tmn are the maximum and minimum temperatures observed in each month. The STmx and STmn are the standard deviation values of the observed maximum and minimum temperatures. The 'v' is the standard normal deviation and the B is the probability of being wet/dry. The B value is calculated according to the formulas given below:

B (W/D)=1-(P(W/D))/PF (3)

B (W/W)=1-(P(W/W))/PF (4)

B (D/D)=(P(D/D))/PF (5)

B (D/W)=(P(D/W))/PF (6)

The P (W/D) is the wet days after a dry day and the P (W/W) is the wet day after a wet day. The PF is a factor based on the probability of wet and dry and is calculated by the formula given below:

PF=P(W\D)(1-(W\D))+P(W\W)(l-P(W\WO) (7)

Descriptive statistical data such as mean, standard error, median value, minimum and maximum for data series and average standard error statistics were used in determining which years some measured climatic data showed excess. An evaluation of the trends in climatic variables is essential for understanding the effect of climate change on temperature, precipitation which in turn, has a direct and adverse impact on hydrological, agricultural and economic. Various statistical methods are available to determine trends in climatic and hydrologic variables. (Arnell and Reynard, 1996; Frich et al. 2002; Udo-Inyang and Edem, 2012; Rahman and Yunsheng, 2017). In meteorological data, the non-normal distribution and the censored character are common and the Kolmogorov-Smirnov is can handle such issues (Kumar et al., 2010; Rahman and Yunsheng, 2017). Therefore, in the present research, these methods were selected to detect the annual and seasonal precipitation trends in Kayseri, Sivas and Yozgat provinces.

3. Results and Discussion

3.1. Graphical Analysis

Figure 2, Figure 3, Figure 4 and Figure 5 presents graphs showing normal histogram and normal curve for spring, summer, autumn, and winter seasons. Temperature data for some months showed the normal distribution. However, many months were found skewed and did not show the normal distribution. In addition, the minimum temperatures were found closer to the observed values than the maximum temperatures. Spring maximum temperatures moved away from the mean, standard deviation increased, and showed a broader distribution (Figure 3). The minimum temperatures showed a closer distribution to the mean. The finding was the opposite for the summer (Figure 4) and winter season temperatures (Figure 5), which showed the normal distribution. In these months, the temperature data showed a more regular distribution with a value close to the mean since rains are more regular.

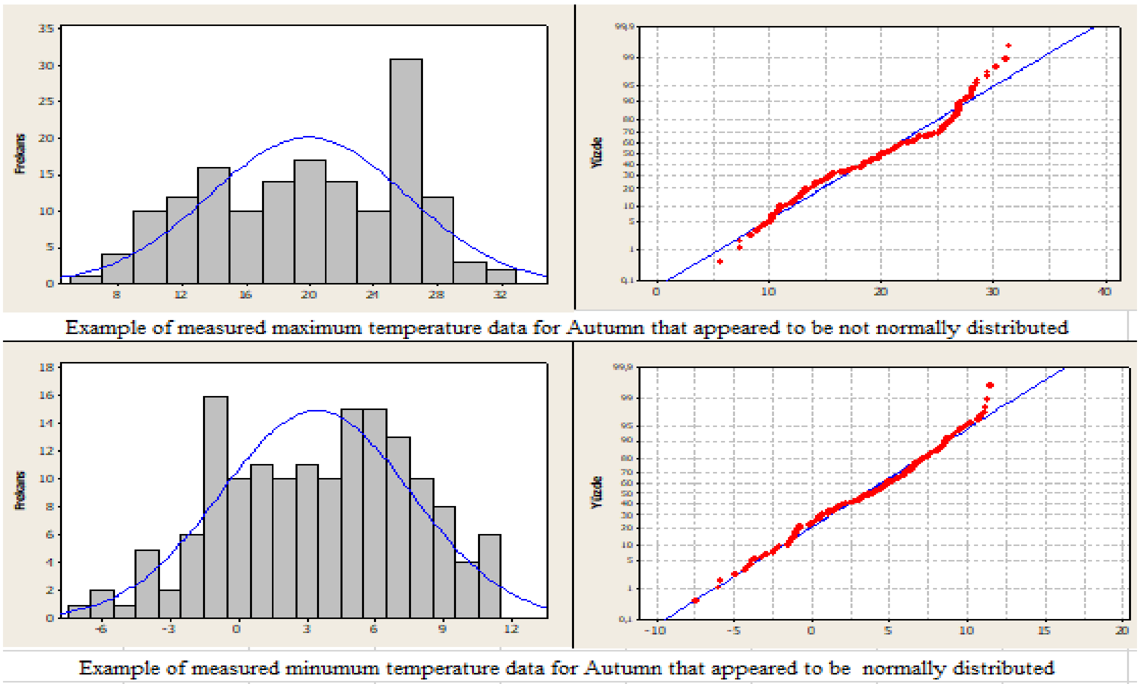


Figure 2. Example of measured temperature data for autumn

Şekil 2. *Sonbahar mevsimi gözlenen sıcaklık*

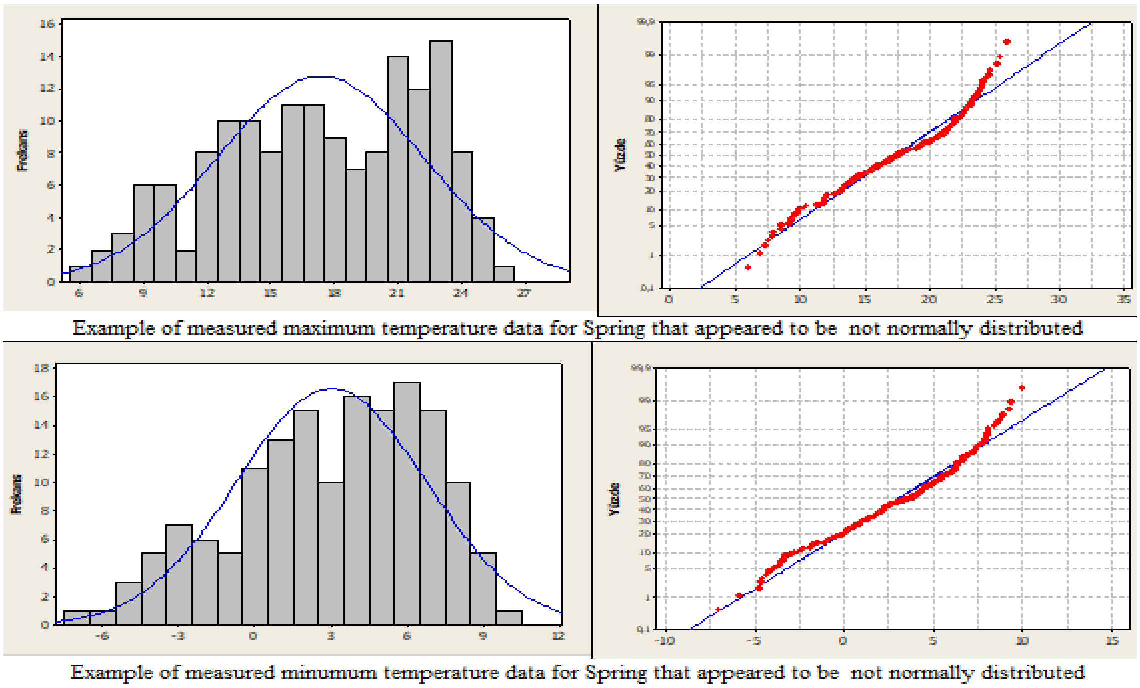


Figure 3. Example of measured temperature data for spring

Şekil 3. *İlkbahar mevsimi gözlenen sıcaklık*

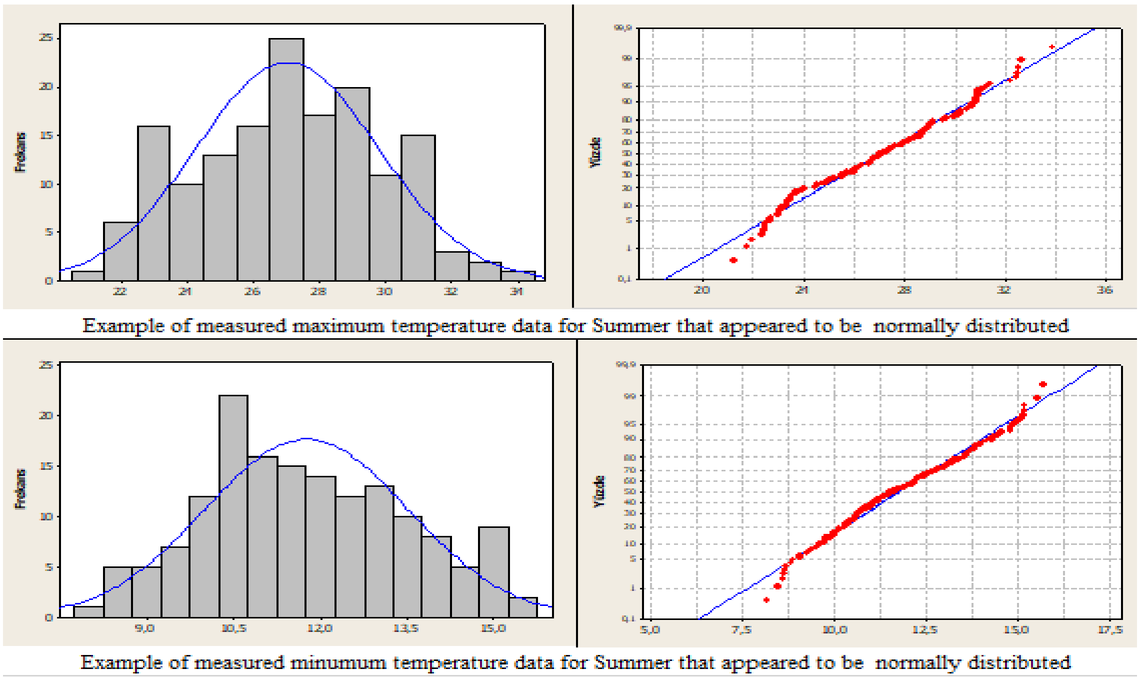
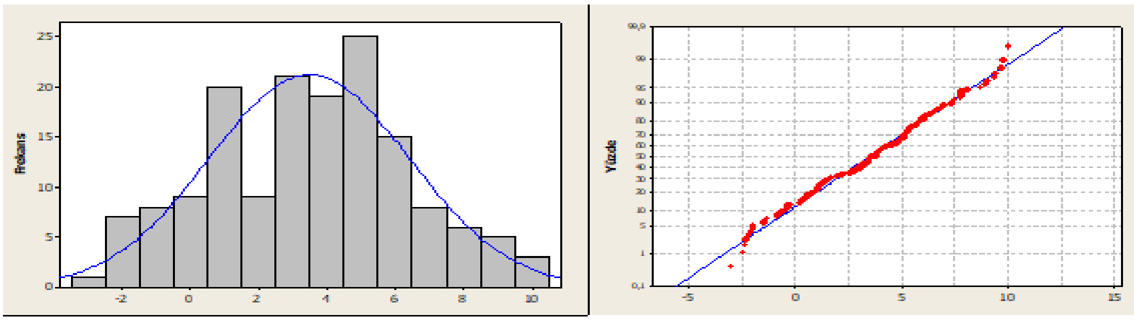
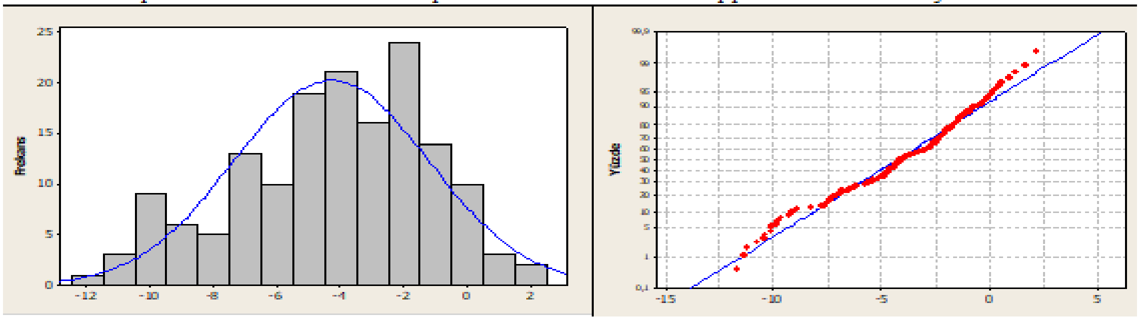


Figure 4.Example of measured temperature data for summer

Şekil 4. *Yaz mevsimi gözlenen sıcaklık*



Example of measured maximum temperature data forWinter that appeared to be normally distributed



Example of measured minumum temperature data forWinter that appeared not to be normally distributed

Figure 5. Example of measured temperature data for winter

Şekil 5. *Kış mevsimi gözlenen sıcaklık*

Table 4. Descriptive statistics of the maximum temperature

Çizelge 4. *Maksimum sıcaklıkların tanımlayıcı istatistikleri*

Stations Names	Analysis	Winter		Spring		Summer		Autumn	
		G	S	G	S	G	S	G	S
Kayseri	Mean	5.45	10.38	17.39	22.87	29.36	35.73	19.84	26.03
	Median	5.65	10.56	17.22	22.91	29.28	35.83	19.88	26.65
	Std. D.	2.36	2.87	1.42	2.14	1.26	3.52	1.25	2.62
	Variance	5.57	8.24	2.00	4.57	1.58	12.37	1.57	7.63
	Minimum	-1.32	3.14	14.67	18.61	26.78	28.78	15.71	19.00
	Maximum	10.56	16.59	21.13	29.06	31.87	43.92	22.49	30.35
Sivas	Mean	2.51	6.66	14.78	19.83	27.09	33.11	18.00	24.24
	Median	2.67	6.70	14.43	19.59	26.94	32.79	17.00	24.36
	Std. D.	2.49	2.96	1.60	1.92	1.47	3.39	1.36	2.63
	Variance	6.19	8.76	2.55	3.69	2.17	11.47	1.86	6.94
	Minimum	-3.77	0.37	11.73	16.68	23.70	25.14	14.45	18.84
	Maximum	8.70	13.64	19.28	26.63	29.94	40.95	21.06	30.14
Yozgat	Mean	3.47	7.61	13.81	19.10	25.23	31.65	16.61	22.22
	Median	3.60	7.69	13.72	18.76	25.10	31.17	16.73	22.05
	Std. D.	1.93	2.32	1.50	2.12	1.41	3.07	1.32	2.22
	Variance	3.72	5.39	2.26	4.89	1.98	9.40	1.75	4.94
	Minimum	-1.94	-0.12	10.63	14.62	22.47	25.13	13.64	17.93
	Maximum	7.88	12.50	17.91	25.06	28.30	40.43	19.41	27.17

Table 5. Descriptive statistics of the minimum temperature
***Çizelge 5**. Minumum sıcaklıkların tanımlayıcı istatistikleri*

Station Name	Analysıs	Winter		Spring		Summer		Autumn	
		G	S	G	S	G	S	G	S
Kayseri	Mean	-5.57	-1.83	3.06	7.16	11.26	15.97	3.38	7.87
	Median	-5.07	-1.83	2.84	7.12	11.59	16.01	3.41	8.48
	Std. D.	2.68	3.07	1.27	1.67	1.80	2.91	1.62	2.29
	Variance	7.15	9.43	1.61	2.78	3.25	8.45	2.61	5.22
	Minimum	-14.35	-12.15	0.62	4.00	8.00	9.56	0.26	1.07
	Maximum	-0.55	3.55	5.93	10.18	14.81	23.96	6.30	12.09
Sivas	Mean	-5.71	-2.35	3.36	7.36	11.78	16.44	4.29	9.04
	Median	-5.35	-2.40	3.40	7.38	11.63	16.13	4.33	8.99
	Std. D.	2.77	3.21	0.93	1.28	1.15	2.71	1.08	1.89
	Variance	7.69	10.36	0.88	1.65	1.32	7.36	1.17	3.60
	Minimum	-12.63	-10.29	1.39	4.57	9.84	10.97	2.13	4.62
	Maximum	-.67	4.15	5.71	11.50	14.40	22.24	6.43	13.34
Yozgat	Mean	-4.29	-0.88	3.18	7.44	12.33	17.48	5.20	9.68
	Median	-4.09	-0.79	3.05	7.19	12.36	17.26	5.18	9.72
	Std. D.	2.14	2.50	1.00	1.64	1.17	2.43	0.98	1.69
	Variance	4.59	6.28	1.00	2.70	1.38	5.93	.962	2.86
	Minimum	-9.39	-7.92	0.40	3.58	10.28	12.57	3.50	5.28
	Maximum	0.03	4.19	5.98	11.74	15.18	24.17	7.48	13.27

3.2. The Conformity to Normal Distribution Analysis

The Kolmogorov-Smirnov goodness of fit test was applied to the daily maximum and minimum temperature data for a total of 36 months (12 months maximum and minimum data sets were created for all 3 stations). Significance levels for each station are presented in Table 6. The maximum and minimum temperatures were generally not normally distributed. The empirical and simulated temperature values of Yozgat station for April showed the normal distribution (Table 6).

presents the temperature values simulated by the CLIGEN climate model. Accordingly, temperatures of Kayseri station showed the normal distribution in April, May, and June. In Sivas station, temperatures showed the normal distribution in March, April, May, and June (Table 6). The simulated data in Yozgat station in February, April, and June showed the normal distribution. As presented in Table 6, the simulated temperatures for all three stations showed the normal distribution for April and June. The CLIGEN simulates in consideration of the possible wet/dry days. Precipitation is very frequent and regular in April, so the possibility of a wet day is high. In June, a dry day is more likely due to the rare rains.

The situation regarding the temperatures is also valid for minimum temperatures (Table 6). Both the empirical and simulated temperatures at the Kayseri station in April and July temperatures showed the normal distribution. Temperature values observed and simulated of Yozgat station showed the normal distribution in April. The values observed in August showed the normal distribution, while the values simulated by the CLIGEN did not. Since there is no precipitation this month, the data simulated by the model did not show the normal distribution. The temperature values observed for all months in Sivas station did not show the normal distribution. Temperature values simulated by the CLIGEN for April and May showed the normal distribution.

When the temperature values analyzed by the Kolmogorov-Smirnov test for all months are examined, it could be seen that the geographical locations of the stations are quite effective. The impact of the continental climate was very much manifested in all three stations. Temperature differences between summer and winter, day and night are high in Yozgat station. Due to the transition in the spring months, the temperatures showed a more regular distribution. Sivas station is located in an area where four seasons are different from each other. Snow are falling in the winter stays on the soil surface for 4-5 months. Very different between the day and night temperatures are high. Heavy rains occur in spring, and the summer months are quite dry. At the beginning of spring season, temperatures are on the rise and show a more regular distribution. Changing the temperature is a result of the change in mean or variance or both. The mean is affected due to the distorted distribution observed especially in the spring and autumn seasons. This situation in precipitation affects the dry day length and causes climate changes. Since the study area has very variable climate features, simulation data with CLIGEN did not show the normal distribution for many months.

Raggad (2018) statistically investigated the change in the extreme temperatures in Saudi Arabia between 1985 and 2014. In the study, it was reported that the maximum temperature values were not normally distributed and were in an increasing trend. Klein Tank and Können (2003) applied trend analysis to the data received from over 100 meteorological stations in Europe. In the study investigating the maximum and minimum temperatures between 1946-1999, it was reported that the data did not show the normal distribution in the lower period of 1946-1975.

Table 6. Significance levels for the Kolmogorov-Smirnov test of normality
Çizelge 6. *Kolmogorov-Smirnov testi için önem seviyeleri*

Stations Names		Analysis	Months												
			1	2	3	4	5	6	7	8	9	10	11	12	N
KAYSERİ	G	KS_pval (Max)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-
	S	KS_pval (Max)	0,00	0,00	0,00	**0,15**	**0,15**	**0,15**	0,00	0,00	0,00	0,00	0,00	0,00	3
	G	KS_pval (Min)	0,00	0,00	0,00	**0,08**	0,00	0,00	**0,08**	0,00	0,00	0,00	0,00	0,00	2
	S	KS_pval (Min)	0,00	0,00	0,00	**0,15**	**0,15**	**0,08**	0,00	0,00	0,00	0,00	0,00	0,00	3
SİVAS	G	KS_pval (Max)	0,00	0,00	0,05	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-
	S	KS_pval (Max)	0,00	0,00	**0,10**	**0,15**	**0,15**	**0,15**	0,00	0,00	0,00	**0,06**	0,00	0,00	5
	G	KS_pval (Min)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,00	-
	S	KS_pval (Min)	0,00	0,00	0,00	**0,15**	**0,13**	**0,15**	0,00	0,00	0,00	**0,05**	0,00	0,00	4
YOZGAT	G	KS_pval (Max)	0,00	0,04	0,00	**0,06**	0,00	0,02	0,00	0,00	0,00	0,00	0,00	0,00	1
	S	KS_pval (Max)	0,00	**0,15**	0,00	**0,15**	0,00	**0,15**	0,00	0,00	0,04	0,00	0,00	0,00	3
	G	KS_pval (Min)	0,00	0,00	0,00	**0,15**	0,00	0,00	0,00	**0,10**	0,00	0,00	0,00	0,00	2
	S	KS_pval (Min)	0,00	0,00	0,00	**0,05**	0,00	0,02	0,00	0,00	0,00	0,00	0,00	0,00	1

G: Measured temperatures, S: Simulated temperatures, N: Normal distributions

3.3. Skewness analysis

Table 7 presents the skewness coefficient for the autumn, winter, spring, and summer seasons for each location. Accordingly, it can be seen that the daily maximum and minimum temperatures were skewed. This indicates that there might be deviations from normal distribution. According to the Kolmogorov-Smirnov test, p values were calculated and skewness coefficients were determined according to this value.

The maximum temperatures observed were found negative skew for all seasons. The lowest skew value was observed in winter season. Due to the study area in the Central Anatolia climate zone, the high number of cloudy days affiliated with cold weather and precipitation in the region, the day and night temperatures are very different. The skewness coefficient of winter season rains was the lowest in Kayseri region. In this season, precipitation showed a more regular distribution. For Sivas station, the lowest skew coefficient was observed in summer season. In Yozgat station, the skewness coefficient of the temperatures was lower in winter and summer seasons. The finding was different for maximum temperatures simulated by the CLIGEN. The lowest skew value for Kayseri and Sivas stations was simulated in the winter and autumn seasons. These seasons are the months when the rainy days are high. The temperatures belonging to Yozgat station, were found to have a very low skew value for each season. In addition, the model simulated the summer temperatures to have a positive skew. This conclusion indicates that the model simulates above the observed value.

The minimum temperatures observed all showed negative skewness. When the minimum temperatures in winter are examined for all three stations, it can see that there were quite high negative values. For Kayseri and Yozgat stations, the highest value was seen in winter, and the lowest value was in summer (Table 7). In Sivas station, there were close skew values in winter and spring seasons; the lowest value was determined in the summer. The temperature distributions simulated by the CLIGEN for summer were found similar to the maximum temperature. The model predicted above the observed value.

Table 7. Skewness coefficients for seasons
***Çizelge 7**. Mevsimsel çarpıklık katsayıları*

Stations Names	Parameter	Maxımum Temperature				Minumum Temperature			
		Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
Kayseri	G	-0,13	-0,37	-0,38	-0,37	-0,83	-0,59	-0,02	-0,39
	S	-0,09	-0,25	0,34	-0,16	-0,74	-0,50	0,26	-0,29
Sivas	G	-0,35	-0,36	-0,15	-0,35	-0,67	-0,69	-0,01	-0,43
	S	-0,22	-0,31	0,28	-0,19	-0,58	-0,49	0,22	-0,30
Yozgat	G	-0,06	-0,30	-0,05	-0,24	-0,52	-0,46	-0,04	-0,38
	S	-0,11	-0,09	0,17	-0,08	-0,51	-0,11	0,13	-0,18

3.4. Extreme Temperature Analysis

Extreme hot and cold days were determined from the data set of the observed and simulated temperature values. The observed and simulated values of 52 years period were compared as presented in Figure 6 and Figure 7. Temperature values simulated with the CLIGEN were calculated very close to the observed values. The absolute error value was 1.6 ° C. The average difference at maximum temperatures was 5% and at minimum temperatures was 4%.

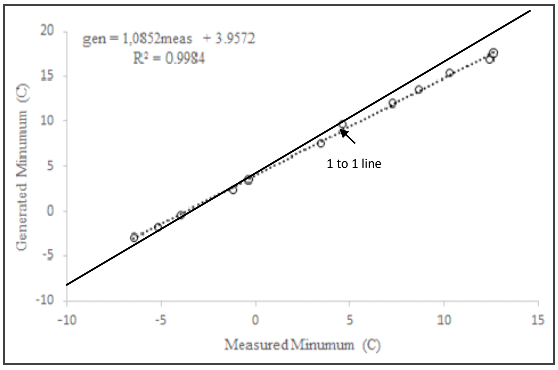


Figure 6. Comparison of generated and measured extreme minimum temperatures for all months
***Şekil 6.** Tüm aylar için gözlenen ve tahmin edilen ekstrem minimum sıcaklıkların karşılaştırılması*

The coefficient of determination between the minimum temperature values was R^2 = 0.99. The cold days simulated from November to May were found higher than the observed value (Figure 6).

The coefficient of determination between the maximum temperature values was R^2 = 0.99, which was quite high. The distribution of the data above the 1: 1 line indicates that the model predicted the observed data. In arid regions, the temperature value increases due to solar radiation (Figure 7).

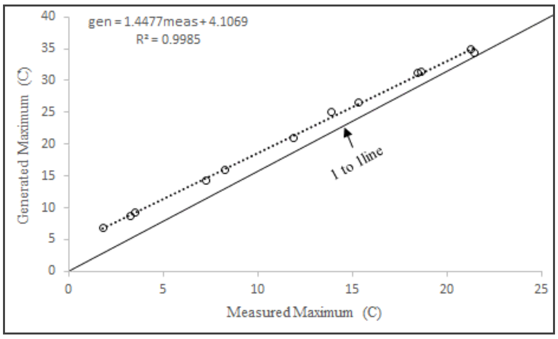


Figure 7. Comparison of generated and measured extreme maximum temperatures for all months
***Şekil 7.** Tüm aylar için gözlenen ve tahmin edilen ekstrem maksimum sıcaklıkların karşılaştırılması*

For extremely hot days during the year, the frequency of simulated days was higher than observed (Figure 8). However, this frequency was lower compared to the minimum temperature. The hottest days observed start from March and end in September, while the simulated hottest days start in February and end in August. The frequency and severity of cold nights decrease depending on the increase in the air temperature. Especially in late spring and early summer, with the increase of temperature, the wind loses its effect.

The occurrence of warm days are seen in the kurtosis that is increased in the latter period, indicating that mostly the variance is due to infrequent extreme deviations. There is also an indication for an increase in the number of cold days. According to Maheras *et al.* (2000) and Feidas *et al.* (2004), the continuing cooling during the winter is due to an increase in the frequency and duration of high-pressure systems over the Central Anatolian region.

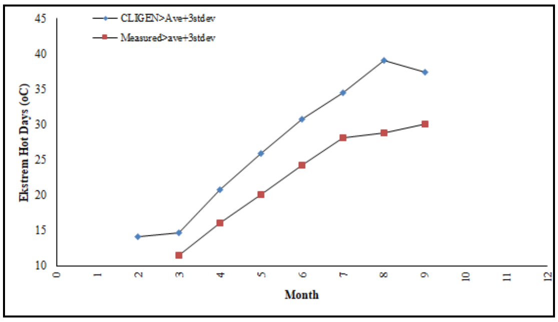


Figure 8. Frequency of extreme hold daily minimum temperatures for measured and generated data (total for all 3 sites in a 50-yr period)

Şekil 8. *Gözlenen ve tahmin edilen ekstrem sıcak günlük minimum sıcaklıkların dağılımı (3 çalışma alanı için 50 yıllık zaman aralığı)*

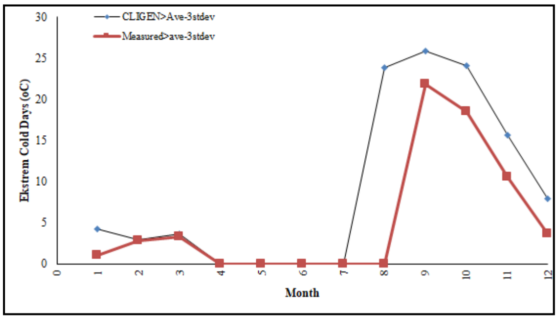


Figure 9. Frequency of extreme cold daily minimum temperatures for measured and generated data (total for all 3 sites in a 50-yr period)

Şekil 9. *Gözlenen ve tahmin edilen ekstrem soğuk günlük minimum sıcaklıkların dağılımı (3 çalışma alanı için 50 yıllık zaman aralığı)*

At extreme cold temperatures, the change in the frequency between simulated and observed cold days is seasonal (Figure 9). The observed cold days were observed from November to March and simulated from November to February.

4. Conclusion

This study investigated whether the maximum and minimum temperature values observed and simulated daily were normally distributed or not. The results indicate that the maximum and minimum temperature data were not normally distributed. These results are not in line with the standard assessment used by climate models using the normal distribution. It was observed that the monthly average and standard deviation calculated by the models were not affected. Therefore, new methods should be developed to prevent the estimation of values that create skew data and do not reflect the observed data.

The skewness in the temperature values is closely related to the seasons and the regional location. The skewness analysis will be a reference in the planning and implementation of further studies on temperature. The use of climate models that evaluate the number of frost days, the length of hot and cold days, the first frost, and similar properties should be expanded in Turkey. These properties are very important in climate change and product simulation studies and are closely related to temperature.

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