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Examining the best probability distributions of meteorological parameters based on annual scale

Yıllık ölçeğe dayalı meteorolojik parametrelerin en iyi olasılık dağılımlarının incelenmesi

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Abstract

Climate and climate related events are still taking the interests of societies as it has a huge impact on live life, energy, economy and sustainability. Meteorological parameters such as precipitation, temperature, humidity provide significant information to humanity to adopt with nature. Within this scope, the aim of this study is to analyze the spatio-temporal variability of mean and maximum temperature, mean relative humidity and total precipitation series and obtain the best fitted probability distributions of them for Karaman, Konya and Ankara Regions of Turkiye considering annual scale by obtaining required data from General Directorate of Meteorology of Turkiye. The spatial distribution of selected meteorological variables has been analyzed by Inverse Distance Weighting (IDW) technique and possible temporal variability of these variables have been examined by the trend tests of Mann Kendall (MKT), Spearman's Rho (SRT), Sen' Slope(SSE). The best fitted distributions of parameters have been analyzed by utilizing the most commonly used probability distributions of Normal, Lognormal, Logistic, Gamma, Weibull, Gumbel, Generalized Extreme Value considering their performance in a set of goodness of fit tests which are Kolmogorov-Smirnov, Anderson Darling, Chi Square, Cramer Von Mises, Akaike Information Criterion, Bayesian Information Criterion and Maximum Likelihood Estimations. The trend results of MKT and SRT have demonstrated that although there has been a variety of trend types (increasing or decreasing) in data series, a few times these trends have been significant when considering α=0.01 significant level while SSE results have been generally detected with increasing trend slopes. The best-fit distribution results have shown that generally Generalized Extreme Value, Logistics and Gamma distributions have been detected as the best fitted distributions while Lognormal, Gumbel and Weibull have been detected with less numbers. The results of this study are expected to be beneficial for climate change action and water resources planning and urban management areas as the study presents significant findings.

Keywords: Climate, Hydrology, Meteorological parameters, Trend, Probability distributions, Turkiye

Öz

İklim ve iklim kaynaklı olaylar; canlı yaşamı, enerji, ekonomi ve sürdürülebilirlik üstünde büyük bir etkisi olması nedeniyle toplumların halen dikkatini çekmektedir. Yağış, sıcaklık ve nem gibi meteorolojik parametreler insanoğluna doğaya adapte olmak için önemli bilgiler sağlar. Bu kapsamda, bu çalışmanın amacı gerekli verilerin Türkiye'nin Meteoroloji Genel Müdürlüğünden temin edilip Türkiye'nin Karaman, Konya ve Ankara Bölgeleri için yıllık ölçek dikkate alınarak ortalama ve maksimum sıcaklık, ortalama nispi nem ve toplam yağış serileri için alansal ve zamansal değişkenliği analiz etmek ve bu seriler için en uygun olasılık dağılımlarını elde etmektir. Seçilen meteorolojik parametrelerinin alansal dağılımı Ters Mesafe Ağırlıklı Yöntem ile, bu parametrelerin olası değişkenliği ise Mann-Kendall testi (MKT), Spearman'ın Rho testi (SRT) ve Sen'in eğim testi (SSE) ile yapılmıştır. Parametrelerin en iyi dağılımları, sıkça kullanılan olasılık dağılımlar olan Normal, Lognormal, Lojistik, Gamma, Weibull, Gumbel ve Genelleştirilmiş Aşırı Değer dağılımlarının Kolmogorov-Smirnov, Anderson Darling, Ki-Kare, Cramer Von Mises, Akaike Bilgi Kriteri, Bayesian Bilgi Kriteri ve Maksimum Olabilirlik Tahminlerinden oluşan bir dizi uyumluluk testlerindeki performansa göre analiz edilmiştir. MKT ve SRT trend test sonuçları veri serilerinde çeşitli trend tipleri (artan veya azalan) tespit edilmesine rağmen, bu trendler α=0.01 anlamlılık seviyesi dikkate alındığında birkaç kez anlamlı olduğunu gösterirken, SSE sonuçları genellikle artan trendlerle tespit edilmiştir. En uygun dağılım sonuçları genel olarak Genelleştirilmiş Aşırı Değer, Lojistik ve Gama dağılımlarının en iyi uyum sağlayan dağılımlar olarak tespit edildiğini; Lognormal, Gumbel ve Weibull dağılımlarının daha az sayıda tespit edildiğini göstermiştir. Bu çalışmanın sunduğu önemli bulgular doğrultusunda, sonuçlarının iklim eylem planları, su kaynaklarının planlanması ve kentsel yönetim alanlarında faydalı olması beklenmektedir.

Anahtar kelimeler: *İklim*, *Hidroloji, Meteorolojik parametreler, Trend, Olasılık dağılımları, Türkiye*

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1. Introduction

Climate and climate related events are continuously taking the interest of humanity as the climate impacts life of the lives, environment, availability of water resources and sectors of production, energy, agriculture either directly or indirectly. The World Meteorological Organization (WMO) reports that climate related hazards have resulted in more than 2 million deaths and economic damages totaling $3.64 trillion over the last five decades (Wixson & Cooley, 2023; Lei & Xu, 2025). Many times, climate change has been reported as a cause of extreme hydrological events such as droughts and floods (Granata et al., 2025; Kaine & Wright, 2025; Wei et al., 2025). These facts force to governments and local authorities develops policies, disaster plans considering updated information in order to keep sustainability and socio-economic life.

Meteorological parameters such as precipitation, temperature, humidity, evaporation and their records provide important information from nature and hydrologic cycle for humanity particularly in the preparing of climate action plans, water resources planning and management, designing of infrastructures and hydraulic structures. Monitoring the variability of these parameters continuously have critical role in climate change mitigation. In many recent research studies such as (Saplıoğlu & Dahir, 2018; Ülke & Özkoca, 2018; Avşaroğlu et al., 2021; Şen & Aksu, 2021; Esit et al., 2024; Kaltakkıran, 2024; Öğ et al., 2024; Acar et al., 2025) trends of various meteorological data time series have been examined by at least one of the tests of Mann-Kendall, Spearman's Rho, Innovative Trend Analysis and Sen's Slope. As much as meteorological parameters provide significant information and may contain possible significant variabilities, accurate analysis of time series has a significant importance (Aksu et al., 2024; Casas-Castillo et al., 2025). To be able to perform accurate analysis that also increases the precise and decreases the uncertainty in the predictions it is best to work with the best model in the applications of hydrological process (Haddad & Rahman, 2011). Wilks (2011) has emphasized that as atmospheric events behave randomly and demonstrate uncertainty, probabilistic methods are needed for the characterization of the behavior sufficiently. In the literature many distributions such as Normal, Lognormal, Weibull, Gamma, Logistic, Generalized Extreme Value, Gumbel, Pearson III, Exponential have been suggested (Li et al., 2013; Sharma & Ojha, 2019; Kassem et al., 2021; Montes-Pajuelo et al., 2024). Besides, usage of goodness of fit tests in the selection of best fitted distributions have been reported as a common approach (Otiniano et al., 2025).

Based on the literature, recently many studies such as (Khudri & Sadia, 2013; Mamoon & Rahman, 2017; Haddad, 2021; Kassem et al., 2021; Eşit, 2022; de Souza et al., 2025; Otieno et al., 2025; Rosli et al., 2025) have been done for estimation of the best model for meteorological parameters in different parts of the world using probability distributions. From this point, this study aims to analyze spatio-temporal variability and present the best probability distributions of the meteorological variables of mean and maximum temperature, mean relative humidity and total precipitation series in annual scale for three important cities of Turkey which are Konya, Karaman and Ankara Regions that have not been studied by considering both spatio-temporal variability and the best fit distributions. In this context at the first step, the spatial distribution of selected meteorological variables is examined by Inverse Distance Weighting (IDW) and the trend detection is examined by the tests of Mann-Kendall (MKT), Spearman's Rho (SRT) considering α=0.01 significance level while trend slopes are determined by Sen's slope estimator (SSE). In the second step, the best fit distributions of selected meteorological variables in annual scale are determined using Normal, Lognormal, Logistic, Weibull, Gamma, Generalized Extreme Value, Gumbel distributions considering their performance in a set of goodness of fit tests which are Kolmogorov-Smirnov, Anderson Darling, Chi Square, Cramer Von Mises, Akaike Information Criterion, Bayesian Information Criterion and Maximum Likelihood Estimations. The best fitted distributions are tested by a graphical test. The required data has been taken from General Directorate of Meteorology of Turkiye. The study is significant as it presents a comprehensive analysis combining spatio-temporal variability and probability distribution modelling of a set of essential meteorological variables for Konya, Karaman and Ankara regions. The findings of this study are expected to be beneficial for climate change action and water resources planning and urban management areas.

2. Methodology

2.1. Spatial distribution of meteorological parameters by Inverse Distance Weighting (IDW) technique

IDW is a spatial interpolation technique that has been used in recent studies such as (Katipoğlu, 2022; Deger et al., 2025) for different purposes of monitoring in hydrology field. In this study IDW has been applied for spatial distribution of meteorological parameters using a licensed version of ArcGIS software program.

2.2 Trend detection tests

Many recent studies such as (Körük et al., 2023; Rahman et al., 2025; Rwema et al., 2025) have presented that trend detection is beneficial for understanding future changes of meteorological variables. In the study, trend detection has been performed by Mann-Kendall Test (MKT) (Mann, 1945; Kendall, 1975) and Spearman's Rho Test (SRT) (Spearman, 1961) considering α=0.01 significance level while Sen's Slope Estimator (SSE) (Sen, 1968) have been used for trend slope determination.

2.2. Probability distributions

In the study, the probability distributions of Normal, Lognormal, Gamma, Logistic, Weibull, Gumbel, Generalized Extreme Value have been utilized to predict the best model of meteorological parameters. These probability functions have been utilized commonly in many studies such as (Langat et al., 2019; Eşit, 2022; Abu Arra & Şişman, 2025; Deger et al., 2025) for different purposes in the field of hydrology and water resources. The probability distribution functions (pdf) *f(x)* and cumulative distribution function (cdf) *F(x)* of these distributions have been given in Table 1.

Table 1. The pdf and cdf of used probability distribution functions

Distribution	Probability Distribution Function	Cumulative Distribution Function	Reference
Normal	$f(x)=\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{1}{2\sigma^2}(x-\mu)^2}$	$F(x)=\int_{-\infty}^{u}\frac{1}{\sqrt{2\pi}}e^{-\frac{t^2}{2}}dt$	(Hamed & Rao, 2019)
Lognormal	$f(x)=\frac{1}{x}\frac{1}{\sigma\sqrt{2\pi}}\exp\left(-\frac{(lnx-\mu)^2}{2\sigma^2}\right)$	$F(x)=\frac{1}{2}\left[1+erf\left(\frac{(lnx)-u}{\sigma\sqrt{2}}\right)\right]$	(Ng et al., 2018; J et al., 2019)
Gamma	$f(x)=\frac{\left(\frac{x-\mu}{\beta}\right)^{\gamma-1}exp\left(-\frac{x-\mu}{\beta}\right)}{\beta\Gamma(\gamma)}$ where Γ is gamma function and can be determined $\Gamma(a)=\int_0^{\infty}t^{a-1}e^{-t}dt$	$F(x)=\frac{\Gamma_x(\gamma)}{\Gamma(\gamma)}$	(Eşit, 2022)
Logistic	$f(x)=\frac{e^{-\frac{x-\mu}{s}}}{s\left(1+e^{-\frac{x-\mu}{s}}\right)^2}$	$F_X(x)=\int_{-\infty}^{x}xf_X(x)dx=\frac{1}{1+e^{-\frac{x-\mu}{s}}}$	(Stauffer et al., 2017; Hamed & Rao, 2019)
Weibull	$f(x)=\frac{\Upsilon}{\alpha}\left(\frac{x-\mu}{\alpha}\right)^{\Upsilon-1}e^{-\left(\frac{x-\mu}{\alpha}\right)^{\Upsilon}}$	$F(x)=1-e^{-\left(\frac{x}{\alpha}\right)^{\Upsilon}}$	(Lai et al., 2006; Abdolmanafi et al., 2025)
Gumbel	$f(x)=\exp\left(-x-\exp(-x)\right)$	$F(x)=\exp\left(-\exp\left(-\frac{x-a}{b}\right)\right)$	(Chattamvelli & Shanmugam, 2021)
Generalized Extreme Value (GEV)	$f(y;\xi;\mu;\sigma)=\frac{1}{\sigma}\left[1+\xi\left(\frac{y-\mu}{\sigma}\right)\right]^{-\frac{1}{\xi}-1}exp\left\{-\left[1+\xi\left(\frac{y-\mu}{\sigma}\right)\right]^{-\frac{1}{\xi}}\right\}$, $if\ \xi\neq 0$	$F(y;\xi;\mu;\sigma)=\left\{exp-\left\{1+\xi\left(\frac{y-\mu}{\sigma}\right)^{-\frac{1}{\xi}}\right\}\right\}$, $if\ \xi\neq 0$	(Otiniano et al., 2025)

2.3. Goodness of fit tests

In data related researches of hydrology, working with the best models increase the precise of predictions. Therefore, a set of well-known goodness of fit tests which are Kolmogorov-Smirnov (K-S) (Smirnov, 1948), Cramer Von Mises (CVM) (Laio, 2004), Anderson-Darling (AD) (Stephens, 1974), Akaike Information Criterion (AIC) (Akaike, 1976), Bayesian Information Criterion (BIC) (Stone, 1979), Chi-Square (CH) (Hamed & Rao, 2019) and Loglikelihood are applied for the selection of the best fit distribution. The parameters of the best fit distributions are determined by Maximum Loglikelihood Estimations (MLE) (Katikas et al., 2021).

3. Data and study area

Ankara, Konya and Karaman regions are found in Central Anatolia Region of Turkiye. In Central Anatolia Region which is surrounded by mountains, experiences a continental climate type in which large temperature

differences are seen between winter and summer seasons (Kızılelma et al., 2015). Ankara which is the capital city of the country and found in the center of Central Anatolia Region has the surface area of 25.706 km^2 (Ünal & Özel, 2023). Konya that is home of 2.5 million people roughly is the country's most crowded and largest province with a surface area exceeding 40.000 km^2 (Gezgin & Gündüz, 2025). Karaman whose big part is found in Central Anatolia Region has the surface area of 9393 km^2 (Candan et al., 2018). To achieve the goal of the study, required data of temperature (°C), relative humidity (%) and precipitation have been obtained from General Directorate of Meteorology of Turkiye (MGM). A summarize of data types and information of stations have been given Table 2 while the locations of the stations and study area have been illustrated in Figure 1.

Table 2. The information of used meteorological variables in the study area

Station	Latitude (N)	Longitude (E)	Height (m)	Meteorological Parameters	Data Range
17246 Karaman	37.1932	33.2202	1018	Annual Maximum Temperature (°C) Annual Mean Relative Humidity (%) Annual Mean Temperature (°C) Annual Total Precipitation (mm)	1951-2024 1959-2024 1951-2024
17244 Konya	37.9837	32.574	1031	Annual Maximum Temperature (°C) Annual Mean Relative Humidity (%) Annual Mean Temperature (°C) Annual Total Precipitation (mm)	1950-2024
17130 Ankara Bölge	39.9727	32.8637	891	Annual Maximum Temperature (°C) Annual Mean Relative Humidity (%) Annual Mean Temperature (°C) Annual Total Precipitation (mm)	1950-2024
17128 Esenboğa Havalimanı	40.124	32.9992	959	Annual Maximum Temperature (°C) Annual Mean Relative Humidity (%) Annual Mean Temperature (°C) Annual Total Precipitation (mm)	1956-2024

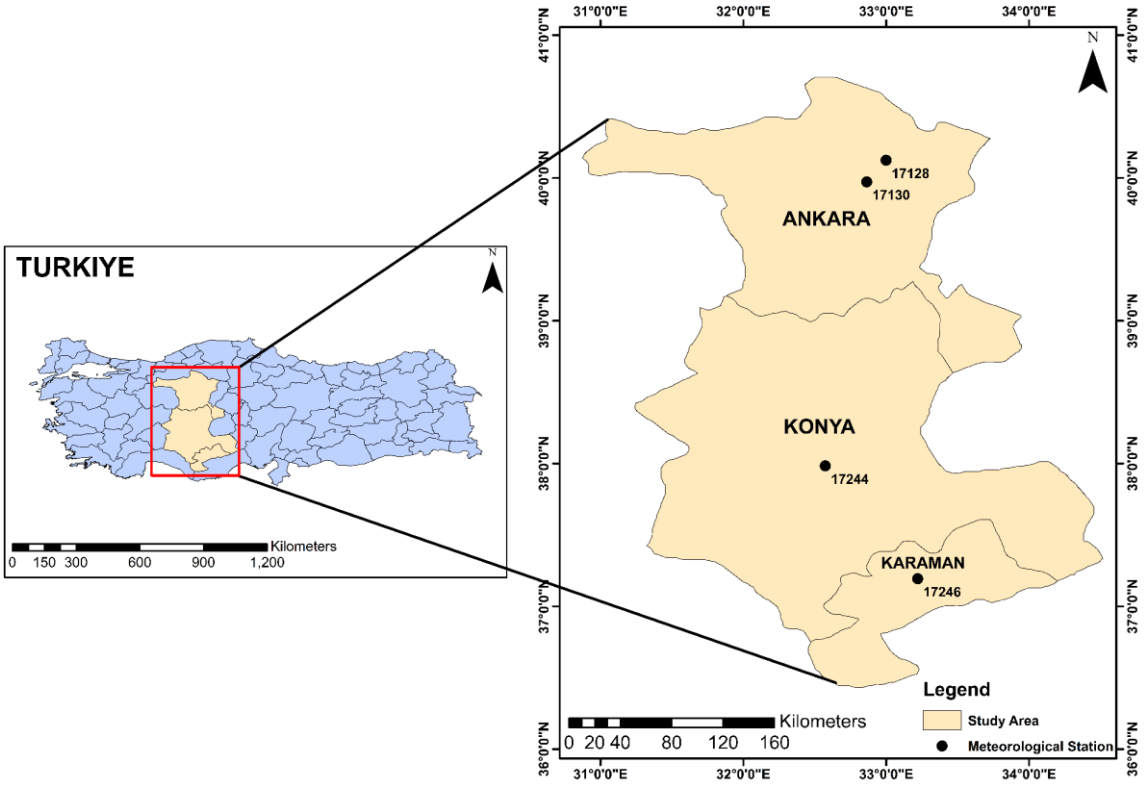

Figure 1. Study area and location of selected meteorological stations

4. Results and discussion

4.1. Spatial distribution analysis of meteorological parameters

For a detailed spatial analysis of meteorological variables in their data ranges, Figure 2 has been constructed. As it can be seen from the figure that, annual mean temperatures vary between 10.3-12.13 (°C) and it is decreasing from south to north except at a small portion around 17130-station. With a distribution range of 35.92-37.14 °C, annual mean maximum temperatures have been higher around 17246-Karaman and 17130-Ankara Bölge Stations while it is lower around 17244 and 17128 stations. When it comes to annual mean relative humidity, it has distributed to whole area with a range of 59.69-65.03 (%) and it is increasing from south to north except at a small portion around 17130-station. Annual mean total precipitation varies from location to location with a total distribution range of 322.8-406.5 mm. While it has been seen with the highest rates in north sides, it has been recorded with the smallest around 17244-Konya station.

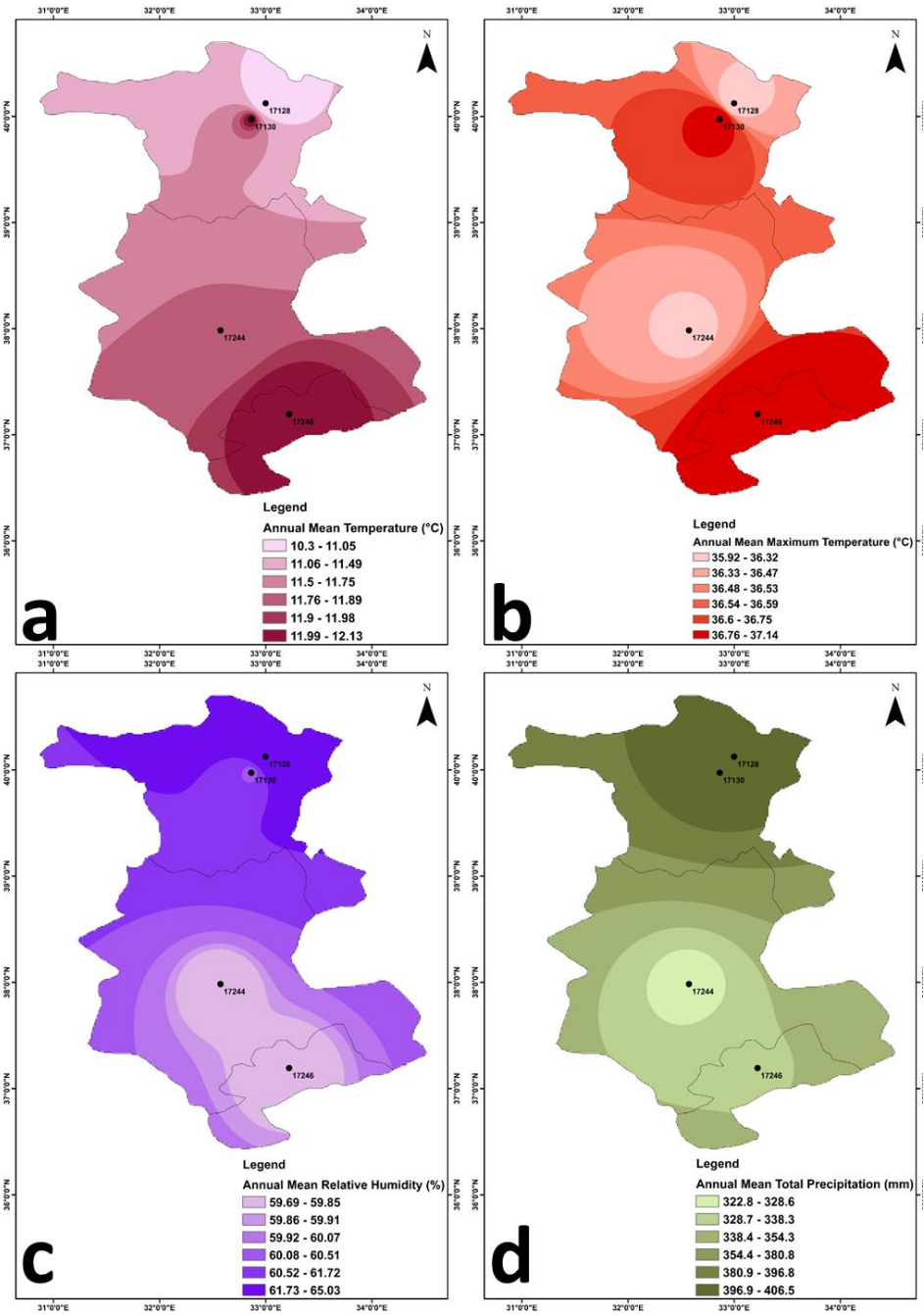

Figure 2. Spatial distribution of meteorological variables over study area, a) annual mean temperature (°C), b) annual mean maximum temperature (°C), c) annual mean relative humidity (%), d) annual mean total precipitation (mm)

4.2. Trend detection analysis

In the study, for examining possible temporal variabilities in data series, trend detection tests of MKT and SRT have been applied and trend slopes of the series have been determined by SSE. The results of these tests have been presented by Table 3. Beginning with the results of the MKT and SRT test, the trend results have been associated with different colors in order to separate the trend types and significant (or non-significant) cases considering α=0.01 with an easier understanding and more effective way. Based on trend types, there has been a prevalence of increasing trends. In all mean and maximum temperature series of the stations, in annual mean relative humidity (SRT) and annual total precipitation series of 17244 and annual mean relative humidity and annual total precipitation series of 17130 stations increasing trends have been detected. Decreasing trends have been detected in annual mean relative humidity series and annual total precipitation series of 17246 and 17128 stations and annual mean relative humidity (MKT) of 17244. As it can be seen from the table that although there has been a variety of trend types in data series, a few times these trends have been significant. For example, only annual mean relative humidity series of 17246-Karaman station has been detected with significantly decreasing trends while annual mean temperature series of 17246, 17130 and 17128 stations, and annual maximum temperature series of 17244 and 17128 stations have been detected with significant increasing trends. In comparison, MKT and SRT have given similar trend types in non-significant cases except at annual mean relative humidity series of 17244 Konya station while in all significant cases, MKT and SRT have a good agreement as well. In Table 3 for easiness, SSE results have been demonstrated with "↑" and "↓" in order to describe increasing trend slopes and decreasing trends slopes respectively. Based on the results, annual mean relative humidity series of 17246, 17244, 17128 stations and annual total precipitation series of 17246 and 17128 stations have been detected with decreasing trend slopes while the rest of the series have been detected with increasing trend slopes. From a point of view, MKT, SRT, SSE have given similar results in terms of trend types except at annual mean relative humidity series of 17244 Konya station that has decreasing trend type with MKT, SSE and increasing trend with SRT.

Table 3. Trend results of meteorological parameters

Station	Meteorological Parameters	MKT	SRT		SSE
17246 Karaman	Annual Maximum Temperature (°C)	1.5178	1.5395	↑	0.0148
	Annual Mean Relative Humidity (%)	-6.6908	-6.1653	↓	-0.1582
	Annual Mean Temperature (°C)	3.9406	3.7316	↑	0.0241
	Annual Total Precipitation (mm)	-0.7637	-0.6851	↓	-0.3909
17244 Konya	Annual Maximum Temperature (°C)	2.6751	2.6919	↑	0.0258
	Annual Mean Relative Humidity (%)	-0.0111	0.1589	↓	-0.0003
	Annual Mean Temperature (°C)	0.8247	0.9231	↑	0.0052
	Annual Total Precipitation (mm)	1.2728	1.2159	↑	0.6747
17130 Ankara Bölge	Annual Maximum Temperature (°C)	2.2099	2.2089	↑	0.0208
	Annual Mean Relative Humidity (%)	2.4019	2.2793	↑	0.0367
	Annual Mean Temperature (°C)	3.0827	2.9616	↑	0.0183
	Annual Total Precipitation (mm)	1.1400	1.2479	↑	0.7158
17128 Esenboğa Havalimanı	Annual Maximum Temperature (°C)	3.3561	3.4774	↑	0.0357
	Annual Mean Relative Humidity (%)	-0.2878	-0.5417	↓	-0.0060
	Annual Mean Temperature (°C)	3.6750	3.6439	↑	0.0241
	Annual Total Precipitation (mm)	-0.1218	-0.3014	↓	-0.0581
	Significant decreasing trend at α=0.01 significance level (Z = -2.576)				
	Non-significant decreasing trend at α=0.01 significance level (Z = -2.576)				
	Significant increasing trend at α=0.01 significance level (Z = 2.576)				
	Non-significant increasing trend at α=0.01 significance level (Z = 2.576)				
↓	Decreasing trend slope				
↑	Increasing trend slope				

In another assessment, when the trend types are considered, the individual series of 17246 and 17128 are similar while 17244 and 17130 series are similar except at mean relative humidity series. While temperature series have been detected totally with increasing trends, the relative humidity and total precipitation series have been more variable. Among 4 stations, only 17130 Ankara station have been detected with increasing trends in all time series. Based on the literature review, many researchers such as (Ülke & Özkoca, 2018; Gümüş et al., 2023; Esit et al., 2024; Kartal et al., 2024; Kaya et al., 2024) have found increasing trends in temperature series in different parts of Turkiye. These increasing trends in temperature records can be seen in different parts of the world (Toma et al., 2022; Dan'azumi & Ibrahim, 2023; Qadem & Tayfur, 2024; Rahman et al., 2025). Katipoğlu (2022) has found decreasing trends in annual mean relative humidity series using different trend techniques for Bursa region while Değer & Yüce (2024) have reported increasing trends for annual mean relative humidity series for Şanlıurfa Region. Esit et al. (2024) have found non-significant decreasing trends in annual precipitation series for Van Region. Akçay et al. (2023) have reported non-significant increasing trends in annual total precipitation for Gönen, Balıkesir, Dursunbey, Tavşanlı, Bursa stations, non-significant decreasing trends Keles station by MKT test. The findings of this research and the finding of the studies referenced show that there is a variability in humidity and precipitation series. Therefore, the results of this is study is compatible with the findings of other studies.

4.3. The best fit distribution analysis

The probability distributions and goodness of fit tests have been applied to each data series in order to obtain the best model. In a certain goodness of fit test, the distribution having the smallest statistics is selected. Then a distribution is specified as the best fitted distribution when it gets the superiority among all distributions in terms of number of selections in the tests. To make this selection clearer, all numerical results have been given by Table 4, 5, 6 and 7. Selected distributions and their statistics have been shown by bold text. For example, in annual maximum temperature analysis of 17246-Karaman station Logistic distribution has had the smallest statistic in K-S, CVM, AD, CS while Lognormal has the smallest in AIC, BIC and GEV has a greater value in Loglikelihood. Based on this, Logistic distribution has been the best distribution.

Table 4. The best fit distribution analysis of 17246 Karaman Meteorological Station

Meteorological parameters	Distributions	Goodness of fit tests						
		K-S	CVM	AD	AIC	BIC	CS	Loglikelihood
Annual maximum temperature (°C)	Lognormal	0.0589	0.0266	0.1965	**240.6855**	**245.0949**	3.5600	-118.3427
	Logistic	**0.0430**	**0.0184**	**0.1602**	241.4114	245.8208	**2.5068**	-118.7057
	Gamma	0.0615	0.0297	0.2163	240.9708	245.3802	3.6267	-118.4854
	Weibull	0.1231	0.2383	1.6252	258.2177	262.6271	12.2370	-127.1088
	Normal	0.0643	0.0341	0.2507	241.6408	246.0501	3.7162	-118.8204
	Gumbel	0.0932	0.0887	0.5502	243.0393	247.4487	3.9441	-119.5196
	GEV	0.0615	0.0302	0.2007	241.6951	248.3092	3.4859	**-117.8476**
Annual mean relative humidity (%)	Lognormal	0.0841	0.1179	0.6704	369.4382	373.8175	5.8311	-182.7191
	Logistic	0.0802	0.0974	0.6521	372.4365	376.8158	6.3192	-184.2183
	Gamma	0.0818	0.1097	0.6282	369.0163	373.3956	5.6004	-182.5081
	Weibull	0.0713	**0.0446**	0.3851	369.0518	373.4311	4.5350	-182.5259
	Normal	0.0769	0.0953	0.5576	368.3765	**372.7558**	5.2346	-182.1883
	Gumbel	0.1209	0.2129	1.2659	378.9268	383.3061	7.2396	-187.4634
	GEV	**0.0660**	0.0525	**0.3598**	**367.7326**	374.3016	**3.7857**	**-180.8663**
Annual mean temperature (°C)	**Lognormal**	0.0607	**0.0361**	**0.2100**	**195.8348**	**200.2442**	**6.0618**	**-95.9174**
	Logistic	0.0735	0.0554	0.3107	196.9275	201.3369	6.1057	-96.4637
	Gamma	0.0657	0.0400	0.2309	195.8473	200.2567	6.1356	-95.9237
	Weibull	0.1006	0.1712	1.1281	205.9874	210.3968	13.0965	-100.9937
	Normal	0.0754	0.0524	0.3038	196.3728	200.7822	6.4714	-96.1864
	Gumbel	0.0756	0.0845	0.6442	203.4684	207.8778	98.2708	-99.7342
	GEV	**0.0594**	0.0376	0.2307	197.8815	204.4956	12.0027	-95.9408
Annual total precipitation (mm)	Lognormal	0.0544	**0.0281**	0.1970	**755.6628**	**760.0722**	4.0617	-375.8314
	Logistic	0.0608	0.0490	0.4426	761.6124	766.0217	5.3329	-378.8062
	Gamma	0.0586	0.0330	0.2448	756.3294	760.7388	4.0456	-376.1647
	Weibull	0.0960	0.1221	0.8873	765.0401	769.4495	7.9312	-380.5201
	Normal	0.0669	0.0673	0.4999	759.8390	764.2484	4.9437	-377.9195
	Gumbel	0.0702	0.0378	0.2387	756.3148	760.7242	3.8489	-376.1574
	GEV	**0.0532**	0.0286	**0.1954**	757.3660	763.9801	**3.5844**	**-375.6830**

Similarly, GEV, Lognormal and GEV have been the best fit in annual mean relative humidity, annual mean temperature and annual total precipitation series respectively due to their superiority in terms of number of tests in 17246 Karaman station. In 17244 Konya station GEV has been the most suitable distribution in annual maximum temperature and annual mean relative humidity series while Gamma has performed the best in annual mean temperature and annual total precipitation. In 17130 Ankara Bölge station Gamma, Logistic, Gumbel distributions have been the most appropriate fit distributions in annual maximum temperature, annual mean relative humidity and annual mean temperature series respectively. In annual total precipitation series, Gamma and Gumbel have shown better performances equally. In such cases, the distribution whose statistic is closer to selected one has been selected as the best. As it can be seen from the table Gamma distribution is closer to performance of Logistic distribution that has better performance in CVM test. When it comes to 17128-Esenboğa Havalimanı Station Logistic distribution has shown superior performance in the annual maximum temperature and annual total precipitation series while Weibull and GEV have shown the better performances in annual mean relative humidity and annual mean temperature series respectively.

Table 5. The best fit distribution analysis of 17244 Konya Meteorological Station

Meteorological parameters	Distributions	Goodness of fit tests						
		K-S	CVM	AD	AIC	BIC	CS	Loglikelihood
Annual maximum temperature (°C)	Lognormal	**0.0555**	**0.0469**	0.3817	278.0862	282.7212	6.1737	-137.0431
	Logistic	0.0761	0.0549	0.4196	279.7250	284.3600	5.7858	-137.8625
	Gamma	0.0555	0.0492	0.4033	278.5815	283.2165	6.0990	-137.2907
	Weibull	0.1337	0.2735	2.0374	300.6723	305.3073	13.5081	-148.3361
	Normal	0.0577	0.0553	0.4572	279.7006	284.3356	6.0550	-137.8503
	Gumbel	0.0882	0.0842	0.5071	**277.1092**	**281.7442**	4.4972	-136.5546
	GEV	0.0786	0.0510	**0.3345**	277.3582	284.3106	**4.3731**	**-135.6791**
Annual mean relative humidity (%)	Lognormal	**0.0733**	**0.0573**	0.3790	403.3701	408.0051	12.1754	-199.6851
	Logistic	0.0897	0.0873	0.5153	405.4629	410.0979	14.2367	-200.7314
	Gamma	0.0765	0.0600	0.3812	403.1570	407.7919	12.4971	-199.5785
	Weibull	0.1002	0.1571	0.9185	409.5655	414.2005	22.9996	-202.7828
	Normal	0.0829	0.0674	0.3994	**402.9677**	**407.6027**	13.2540	-199.4839
	Gumbel	0.0931	0.1145	1.0161	414.4096	419.0445	22.0984	-205.2048
	GEV	0.0777	0.0589	**0.3651**	404.4458	411.3982	**10.1130**	**-199.2229**
Annual mean temperature (°C)	Lognormal	0.0524	0.0242	0.2139	206.8755	211.5104	7.8505	-101.4377
	Logistic	0.0633	0.0317	0.2624	207.5586	212.1936	8.3856	-101.7793
	Gamma	0.0532	**0.0225**	**0.2107**	**206.6665**	**211.3015**	7.7454	**-101.3333**
	Weibull	0.0935	0.1269	0.9799	216.2429	220.8779	11.5094	-106.1214
	Normal	0.0540	0.0238	0.2341	206.7738	211.4088	**7.6889**	-101.3869
	Gumbel	0.0783	0.1189	0.9129	218.0076	222.6426	20.0951	-107.0038
	GEV	**0.0493**	0.0252	0.2417	208.9414	215.8939	10.9067	-101.4707
Annual total precipitation (mm)	Lognormal	0.0756	0.0484	0.3079	857.8473	862.4823	4.6862	-426.9237
	Logistic	0.0840	0.0704	0.4532	861.7018	866.3368	5.8150	-428.8509
	Gamma	**0.0653**	**0.0421**	**0.2781**	**857.8127**	**862.4477**	**4.3939**	-426.9064
	Weibull	0.0736	0.0972	0.8360	866.6975	871.3325	7.6543	-431.3487
	Normal	0.0839	0.0605	0.4510	861.4841	866.1190	5.0676	-428.7420
	Gumbel	0.0798	0.0687	0.4610	859.9547	864.5897	9.2128	-427.9773
	GEV	0.0694	0.0435	0.2884	859.7529	866.7054	6.6779	**-426.8765**

Table6. The best fit distribution analysis of 17130 Ankara Bölge Meteorological Station

Meteorological parameters	Distributions	Goodness of fit tests						
		K-S	CVM	AD	AIC	BIC	CS	Loglikelihood
Annual maximum temperature (°C)	Lognormal	0.0526	0.0323	0.2206	288.9065	293.5415	5.7488	-142.4532
	Logistic	0.0580	0.0352	0.2228	290.1078	294.7428	5.9247	-143.0539
	Gamma	**0.0510**	0.0311	**0.2180**	**288.8885**	**293.5235**	5.6902	-142.4443
	Weibull	0.1021	0.1424	1.0930	299.4356	304.0706	11.1805	-147.7178
	Normal	0.0535	**0.0294**	0.2214	288.9897	293.6247	5.6575	-142.4949
	Gumbel	0.0958	0.1498	0.9822	298.3466	302.9816	5.7529	-147.1733
	GEV	0.0581	0.0358	0.2596	290.7846	297.7370	**3.5772**	**-142.3923**
Annual mean relative humidity (%)	Lognormal	0.0757	0.0695	0.5228	364.7730	369.4080	5.8584	-180.3865
	Logistic	**0.0420**	**0.0198**	**0.1913**	**360.8211**	**365.4561**	**3.7659**	**-178.4106**
	Gamma	0.0724	0.0620	0.4724	364.1078	368.7428	5.6736	-180.0539
	Weibull	0.0905	0.1058	0.6584	365.6113	370.2463	9.0826	-180.8057
	Normal	0.0666	0.0511	0.3940	362.9613	367.5963	5.4484	-179.4807
	Gumbel	0.1279	0.3972	2.6195	387.4877	392.1226	18.6002	-191.7438
	GEV	0.6302	7.5214	34.2384	2080.6416	2087.5940	66.2042	-1037.3208
Annual mean temperature (°C)	Lognormal	0.0921	0.0755	0.4653	220.3937	225.0287	10.5782	-108.1969
	Logistic	0.0899	0.0927	0.6699	226.0333	230.6682	11.8308	-111.0166
	Gamma	0.0974	0.0845	0.5179	221.0265	225.6614	10.9566	-108.5132
	Weibull	0.1290	0.2193	1.4435	234.4725	239.1075	20.1625	-115.2363
	Normal	0.1074	0.1062	0.6488	222.7060	227.3410	11.9087	-109.3530
	Gumbel	**0.0658**	**0.0448**	**0.3204**	**219.6293**	**224.2643**	**9.2046**	-107.8147
	GEV	0.0669	0.0498	0.3251	220.3448	227.2972	9.8989	**-107.1724**
Annual total precipitation (mm)	Lognormal	0.0600	0.0327	0.2513	871.2508	875.8857	4.0928	-433.6254
	Logistic	0.0495	**0.0257**	0.1992	871.9913	876.6263	3.7669	-433.9957
	Gamma	0.0487	0.0265	**0.1899**	**870.4486**	**875.0835**	4.0966	-433.2243
	Weibull	0.0882	0.1308	0.7816	877.0877	881.7227	8.3978	-436.5439
	Normal	0.0643	0.0498	0.2937	871.7697	876.4047	4.8891	-433.8848
	Gumbel	0.0845	0.0904	0.6524	875.7673	880.4023	8.6447	-435.8837
	GEV	**0.0486**	0.0302	0.2062	872.3746	879.3270	**3.1628**	**-433.1873**

Table 7. The best fit distribution analysis of 17128 Esenboğa Havalimanı Meteorological Station

Meteorological parameters	Distributions	Goodness of fit tests						
		K-S	CVM	AD	AIC	BIC	CS	Loglikelihood
Annual maximum temperature (°C)	Lognormal	0.0564	0.0298	0.2036	278.8826	283.3508	3.8685	-137.4413
	Logistic	**0.0521**	**0.0233**	**0.1564**	**278.2671**	**282.7353**	**3.3440**	**-137.1336**
	Gamma	0.0574	0.0272	0.1923	278.7837	283.2519	3.7874	-137.3919
	Weibull	0.1043	0.1426	1.0468	290.1258	294.5940	9.2676	-143.0629
	Normal	0.0590	0.0240	0.1812	278.7832	283.2514	3.6610	-137.3916
	Gumbel	0.1027	0.1768	1.1670	290.6933	295.1616	7.8419	-143.3467
	GEV	0.0696	0.0432	0.3042	282.1136	288.8160	8.6333	-138.0568
Annual mean relative humidity (%)	Lognormal	0.1217	0.2102	1.1023	368.1109	372.5791	12.7503	-182.0554
	Logistic	0.0921	0.1377	0.8782	368.8084	373.2766	10.2362	-182.4042
	Gamma	0.1184	0.1980	1.0435	367.7335	372.2017	12.1489	-181.8667
	Weibull	**0.0900**	**0.1082**	**0.7712**	370.3827	374.8509	**6.5474**	-183.1913
	Normal	0.1115	0.1743	0.9328	**367.1392**	**371.6074**	11.0107	**-181.5696**
	Gumbel	0.1680	0.4235	2.2264	379.5944	384.0626	21.1402	-187.7972
	GEV	0.6273	6.8687	31.2809	1449.6057	1456.3080	55.0139	-721.8028
Annual mean temperature (°C)	Lognormal	0.0851	0.0372	0.2361	**203.2815**	**207.7497**	9.0188	-99.6407
	Logistic	0.0914	0.0550	0.3861	207.0204	211.4886	11.6548	-101.5102
	Gamma	0.0867	0.0380	0.2492	203.4516	207.9198	9.4771	-99.7258
	Weibull	0.0747	0.1146	0.8605	212.5647	217.0329	16.8924	-104.2823
	Normal	0.0894	0.0452	0.3129	204.3808	208.8491	10.7031	-100.1904
	Gumbel	**0.0667**	0.0633	0.4261	207.0752	211.5434	**8.7872**	-101.5376
	GEV	0.0822	**0.0341**	**0.2189**	204.7073	211.4097	8.8454	**-99.3537**
Annual total precipitation (mm)	Lognormal	0.1003	0.0821	0.5738	813.1193	817.5876	10.4974	-404.5597
	Logistic	**0.0543**	**0.0227**	**0.1882**	809.2076	813.6758	**8.2228**	-402.6038
	Gamma	0.0860	0.0541	0.3900	810.6496	815.1178	9.9187	-403.3248
	Weibull	0.0860	0.0851	0.5714	811.4123	815.8805	13.1794	-403.7061
	Normal	0.0645	0.0374	0.2852	**809.0578**	**813.5260**	10.2655	**-402.5289**
	Gumbel	0.1121	0.1604	1.1046	818.8861	823.3543	12.8817	-407.4431
	GEV	0.0710	0.0474	0.3390	811.0657	817.7680	**8.0346**	-402.5329

Beside of examining the distributions as numerical based on goodness of fit tests, the selected distributions have been examined with graphical approximations. A typical performance of the best fit distributions of 17128-Esenboğa Havalimanı Station have been given in Figure 3. As it can be observed from the figure that selected distributions as the best model the data well.

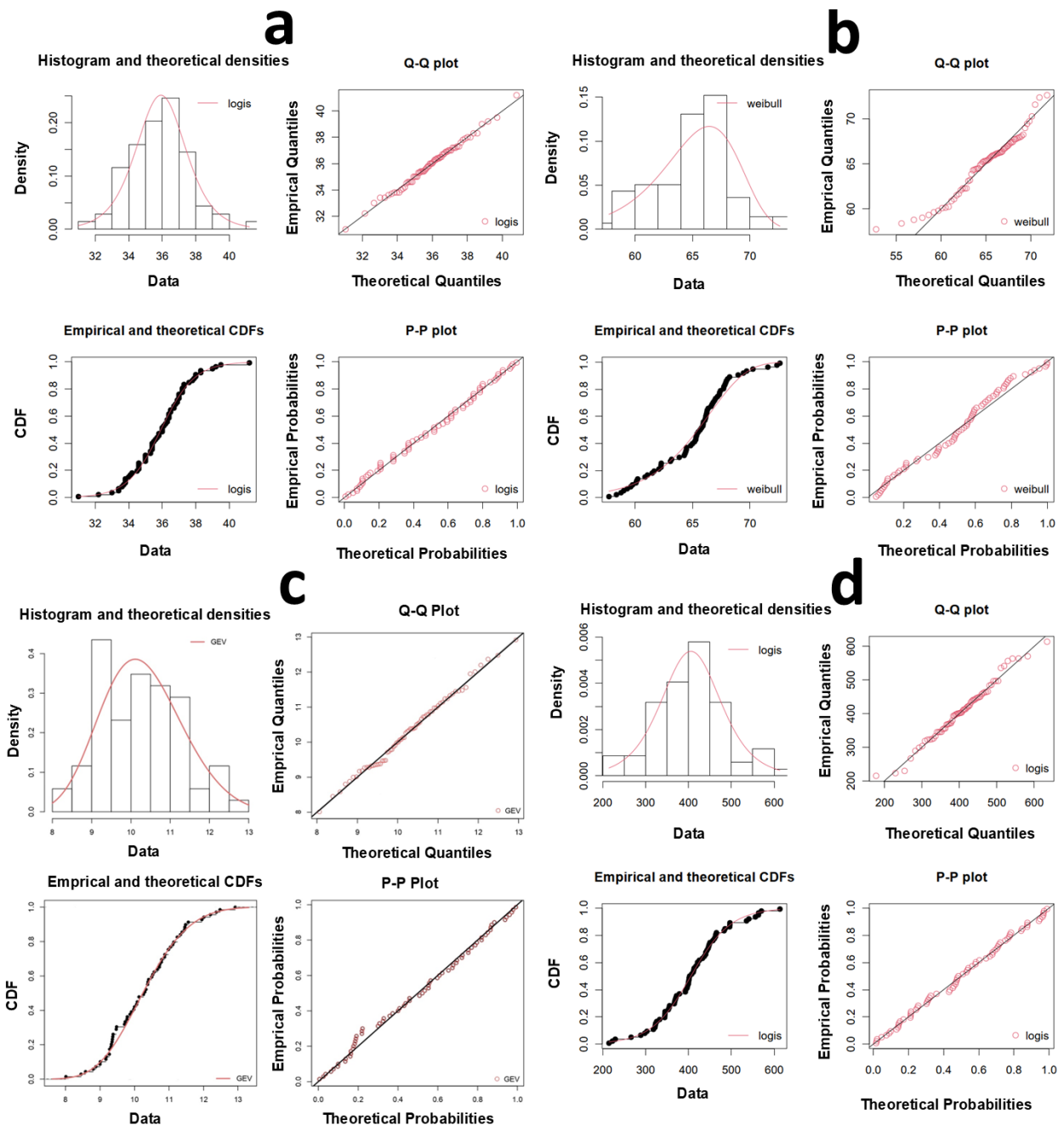

Figure 3. A graphical illustration of the best fit distributions of 17128 Ankara Esenboğa Station a) annual maximum temperature, b) annual mean relative humidity (%), c) annual mean temperature, d) annual total precipitation

In addition to comparison of the distributions in stations, the performances of distributions have been compared in terms of numbers of being the best. To do so, Appendix Table A1 has been constructed by tabling all the best distributions with their parameters and given at the end of the article. As it can be seen, in annual maximum temperature series Logistic distribution has the superiority by being selected 2 times while GEV and Gamma have been selected by one each. In annual mean relative humidity series GEV has better by 2 times while Logistic and Weibull distributions have one each. In annual mean temperature series, the case has been more variable as there has been a different distribution in each station. In annual total precipitation series, Gamma distribution has superiority by being selected 2 times while GEV and Logistics have one each.

In some previous studies, such as (Khudri & Sadia, 2013) GEV distribution has been the best in maximum rainfall data series. Mamoon & Rahman (2017) have reported that GEV has superior performance in the annual maximum rainfall series. Haddad (2021) has put forth that GEV and Normal distributions have fitted best the annual maximum temperature series. Even Rosli et al. (2025) have obtained GEV as the most appropriate fitted distribution for annual maximum series of rainfall in different rainfall durations. In another assessment, de Souza et al. (2025) have found that GEV is the most consistent with for annual maximum temperature series many times. Aksu et al. (2024) have studied for developing rainfall intensity duration frequency curves of Black Sea Region, Turkiye using stationary and non-stationary GEV models. The authors have obtained equal performance of used distribution models in terms of best fits. Eşit (2022) has found that for some of used stations, Gamma and Logistic distribution were the best fits in annual total precipitation series while Gamma and Lognormal distribution were the best for annual mean temperature series, Logistic and Weibull distributions were the best for annual mean relative humidity series in Ankara region. Therefore, from a point view that the findings of these studies confirm that the findings of this study seem to be reasonable and usage of suggested distribution types and goodness of fit tests provide useful information in the prediction of meteorological parameters.

5. Conclusion

In this study, the best fitted distributions of a set of meteorological parameters have been examined utilizing 7 different probability distribution functions and 7 goodness of fit tests for Karaman, Konya and Ankara Regions of Turkiye. In the light of findings, following conclusions have been made:

- Spatio-temporal analysis of meteorological variables are beneficial approaches in assessing different conditions of regions. Spatial distribution analysis of used meteorological variables has shown that annual mean temperatures decrease from south to north except at a small portion around 17130-station, maximum temperatures have been detected as higher around 17246-Karaman and 17130-Ankara Bölge Stations while it is lower around 17244 and 17128 stations. Annual mean relative humidity increases from south to north except at a small portion around 17130-station and annual mean total precipitation has shown variety in which it has been detected with the highest rates in north sides and with the smallest around 17244-Konya station. Temporal variability analysis that has been performed by trend detection tests have provided important findings. The results of MKT and SST have put forward that there has been a prevalence of increasing trends. More than 60% (10/16) of all series have been noted with non-significant trends when considering α=0.01 significance level. In almost all series (15/16) MKT and SRT have given similar results in terms of both trend types and significant (or non-significant) cases. SSE results have demonstrated that many times the series have tended to increase. While temperature series have shown increasing trend behavior, mean relative humidity and total precipitation series have been more variable.
- Probability distribution functions provide significant insights as they inspect the behavior of current data. Goodness of fit tests are useful tools not only for helping the best choice but also provides information by inspecting different sides of distribution functions.
- In annual maximum temperature series, the distributions of Logistics GEV and Gamma have performed a better performance compared to other distributions.
- In annual mean relative humidity series, GEV, Logistic and Weibull distributions have modelled the series better.
- In annual total precipitation series, Gamma, GEV and Logistics distribution series have been the preferred distributions due to their performance in the tests.
- Compared to other series, there has been a variety of distributions in annual mean temperature series. In this series Gumbel and Lognormal has appeared with Gamma and GEV that have performed well in other series as well.
- Since there has been 16 analyses as total (4 stations, 4 parameters), there has been a dominance of GEV, Logistic and Gamma distributions as being selected by 5, 4, 4 respectively while lognormal, Gumbel and Weibull have selected once. Although Normal distribution has appeared with better performances in some trials, it has not been detected as the best fit in any data series of any station.
- The findings of this study can aid to local authorities' policy and decision makers in the planning of climate related actions, water resources planning and urban sustainability. The study presents a comprehensive spatiotemporal variability of selected parameters that can be useful in future regional predictions based on these parameters. Another point is that, identification of the most suitable distribution

type increases the reliability of predictions of extreme event estimation that is critical for design of hydraulic structures and improves flood and drought risk management.

- Although many significant findings have been presented in the paper, the research is limited with used methodologies, approaches and investigated study area. In future works researchers may consider stationary and nonstationary cases together and use other suitable probability distribution families and newly developed suitable techniques.

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Declaration of ethical code

The author of this article declares that the materials and methods used in this study do not require ethics committee approval and/or legal-special permission.

Conflicts of interest

The author declares that there is no conflict of interest.

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APPENDIX

Table A1. The best fit distribution results of all stations

Station	Meteorological parameters	The best fitted distribution	Goodness of fit tests							Distribution parameters
			K-S	CVM	AD	AIC	BIC	CS	Loglikelihood	
17246 Karaman	Annual maximum temperature (°C)	Logistic	0.0430	0.0184	0.1602	241.4114	245.8208	2.5068	-118.7057	Location=37.093 Scale=0.799
	Annual mean relative humidity (%)	GEV	0.0660	0.0525	0.3598	367.7326	374.3016	3.7857	-180.8663	Location=58.580 Scale=3.996 Shape=-0.397
	Annual mean temperature (°C)	Lognormal	0.0607	0.0361	0.2100	195.8348	200.2442	6.0618	-95.9174	Meanlog=2.492 Sdlog=0.083
	Annual total precipitation (mm)	GEV	0.0532	0.0286	0.1954	757.3660	763.9801	3.5844	-375.6830	Location=308.581 Scale=59.387 Shape=-0.104
17244 Konya	Annual maximum temperature (°C)	GEV	0.0786	0.0510	0.3345	277.3582	284.3106	4.3731	-135.6791	Location=35.590 Scale=1.345 Shape=-0.112
	Annual mean relative humidity (%)	GEV	0.0777	0.0589	0.3651	404.4458	411.3982	10.1130	-199.2229	Location=58.480 Scale=3.472 Shape=-0.288
	Annual mean temperature (°C)	Gamma	0.0532	0.0225	0.2107	206.6665	211.3015	7.7454	-101.3333	Shape=158.024 Rate=13.422
	Annual total precipitation (mm)	Gamma	0.0653	0.0421	0.2781	857.8127	862.4477	4.3939	-426.9064	Shape=19.552 Rate=0.0605
17130 Ankara Bölge	Annual maximum temperature (°C)	Gamma	0.0510	0.0311	0.2180	288.8885	293.5235	5.6902	-142.4443	Shape=526.113 Rate=14.172
	Annual mean relative humidity (%)	Logistic	0.0420	0.0198	0.1913	360.8211	365.4561	3.7659	-178.4106	Location=60.124 Scale=1.458
	Annual mean temperature (°C)	Gumbel	0.0658	0.0448	0.3204	219.6293	224.2643	9.2046	-107.8147	Location=11.617 Scale=11.675
	Annual Total Precipitation (mm)	Gamma	0.0487	0.0265	0.1899	870.4486	875.0835	4.0966	-433.2243	Shape=26.295 Rate=0.0648
17128 Esenboğa Havalimanı	Annual maximum temperature (°C)	Logistic	0.0521	0.0233	0.1564	278.2671	282.7353	3.3440	-137.1336	Location=35.922 Scale=0.9931
	Annual mean relative humidity (%)	Weibull	0.0900	0.1082	0.7712	370.3827	374.8509	6.5474	-183.1913	Shape=21.120 Scale=66.601
	Annual mean temperature (°C)	GEV	0.0822	0.0341	0.2189	204.7073	211.4097	8.8454	-99.3537	Location=9.894 Scale=0.9744 Shape=-0.202
	Annual total precipitation (mm)	Logistic	0.0543	0.0227	0.1882	809.2076	813.6758	8.2228	-402.6038	Location=405.683 Scale=46.438