



# Temperature and Precipitation Risk Assessment Under Climate Change Effect in Northeast Algeria

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## Abstract

Climate change impacts on social, economic, industrial, agricultural, and water resource systems tend to increase incrementally with each passing day. Therefore, it is necessary to plan to control its effects, especially with regard to temperature and rainfall events impacting future water resource operation, maintenance and management works. Climate change has a direct influence at the trend of both components temperature and precipitation in increasing or decreasing manner depending on the study area. This paper presents and interprets temperature and rainfall trends for Northeast Algeria. A trend analysis technique was employed along with risk assessment. The modified risks associated with 2-, 5-, 10-, 25-, 50-, 100-, 250, and 500-year return periods are then calculated for each station. This methodology has been applied to precipitation and temperature records for six different meteorological stations in Northeast Algeria. This study confirms that climate change has and will continue to have an impact on temperature and precipitation that should be considered for all infrastructure planning, design, construction, operation, maintenance and optimum management studies in future.

**Keywords** Climate change · Trend analysis · Water structures · Risk analysis

## 1 Introduction

It is hard to talk about twenty-first century water issues without mentioning climate change. Abundant evidence shows that the earth has been warming by several degrees centigrade for the last few decades. It is highly likely that this trend is related to increasing concentrations of carbon

dioxide and other greenhouse gasses in the atmosphere (IPCC 2014). Computer models that simulate the earth's climate tend to agree that the warming trend is likely to continue throughout the rest of this century (Hayhoe et al. 2017). The models show less agreement about projected changes in precipitation but they do tend to agree that some places (primarily the higher latitudes) will be getting wetter and others (primarily the lower latitudes) will be getting drier (Collins et al. 2013). The models also tend to agree that there is likely to be more variation in precipitation. Both floods and droughts are likely to recur with greater frequency, duration and intensity (Parry et al. 2007; Trenberth 2008).

One of the most concerning aspects of climate change is the changes in water cycle. These projected changes can perturb the hydrological cycle; higher temperatures are likely to speed up evaporation from water and land surfaces and speed up transpiration from plants. No matter what happens to precipitation, increased evapotranspiration will dry out soils and leave less water available to flow to streams as well as less water available to infiltrate into the ground and recharge aquifers (Stagl et al. 2014). Warmer temperatures will also cause a shift in precipitation toward less snow and more rain and will lead to earlier and more rapid melting of both the

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seasonal snowpack and glaciers that have persisted for many years (Hoegh-Guldberg et al. 2018). Melting glaciers might cause increased runoff in glacier-fed streams in the short run, but in the long run as glaciers shrink, the melt water runoff will diminish. Along the coasts, rising sea levels are likely to inundate more low-lying land (Stagl et al. 2014).

In areas with increased precipitation, such as the northeast and certain coastal areas, more severe storms, and flooding are expected; however, in the interior of the country, more drought, less stream flow, and less groundwater recharge will eventuate (Wong et al. 2014). Water quality is likely to be affected too (Xia et al. 2015), with warmer temperatures, muddier water from increased erosion, more pollutants from storm water runoff during heavy rains, and in some places, higher contaminant levels due to less stream flow available due to diluting waste water discharges.

Considering the impacts of both climate change and population growth, water scarcity is projected to rise significantly. According to population action international based on the United Nations Medium Population Projections of 1998, more than 2.8 billion people in 48 countries will face water stress or scarcity conditions by the year 2015, of these countries, 40 are in Western Asia, Africa, or Sub-Saharan Africa. By 2050, the number of countries facing water stress or scarcity could rise to 54 with combined population of 4 billion people, about 40% of the projected global population of 9.4 billion (Gardner-Outlaw and Engleman 1997).

Climate change effects will vary significantly, severely affecting infrastructure in different regions of the world (IPCC 2014). As climate change progresses, an important question must be asked—how to modify urban infrastructure dimensions to adapt to these expected impacts (Carter et al. 2015). Usually, urban infrastructure is constructed, assuming a stable climate and until recently climate change has not been taken into account by engineers during the design stage. Now, changes in the frequency and intensity of hydroclimatic averages and extremes will probably change the critical design parameters (Westra et al. 2014). For this reason, a simple risk formulation, which takes into consideration the impact of climate change, must be developed to adapt for these vulnerabilities (Şen 2014; Şen et al. 2017).

The objective of this study is to generate a relationship between the climate trends and the corresponding risk levels for temperature and precipitation data in Northeast region of Algeria. This relationship is required to establish precautionary boundaries to account for climate change impacts.

## 2 Study Area and Data

Algeria is a semi-arid country located in North Africa and has experienced a period of very severe droughts with annual average temperature increases ranging from 0.65 to 1.45 °C

between 1970 and 2004. An average temperature increase comparable with the global average is observed over the period 1906–2005 (Mahmood et al. 2019). Precipitation in Northern Algeria has shown a succession of excessive episodes and deficiency periods compared to historic norms with a large variability (Meddi 2009).

Numerous studies have been conducted on the northern regions of Algeria regarding precipitation and temperature, but they are directed more towards the west than the east (Mohammed and Al-Amin 2018). Bessaklia et al. (2018) studied 23 rainfall stations in the extreme northeast of Algeria over the period 1970–2010 and concluded that the results of Mann–Kendall test show that areas of high precipitation concentration tend to increase. Merabti et al. (2017) examined five locations spread over the Northeast part of the country and inferred that arid and semi-arid zones have experienced a larger number of drought events while the humid and sub-humid locations received greater precipitation events.

The region Northeast of Algeria (Fig. 1) represents all of the territory from the small Kabyle to the Tunisian border, occupying an area of 31,555 km<sup>2</sup> and more than 5 million inhabitants.

Any scientific research needs reliable data in as much detail as possible and, therefore, daily temperature and precipitation data are considered from the National Agency for Hydraulic Resources (ANRH) as well as from Algerian Meteorological Organization since 1982 until 2017 for 35 years. Monthly time series are obtained using daily data. In this paper, monthly average temperature and precipitation records are considered from six stations, which are well distributed within five different watersheds as presented in Table 1.

## 3 Methodology

Risk can mean different things to different people and in different contexts, but in very simple terms, it is how likely is it that someone will be exposed to a bad consequence:

Risk = likelihood \* consequence.

Likelihood == hazard.

Consequence == how bad the outcome will be.

Since the consequences of climate impacts can be so catastrophic for those exposed to the risk, it is important to urgently commit resources to develop a greater understanding of the risk as far as possible, to fill data gaps and overcome key weaknesses in our understanding and act in a precautionary manner rather than postpone action until better data are collected.

Risk assessment and risk models cannot make decisions but they can inform policymakers. Encouraging and developing a culture of risk identification, risk understanding, risk

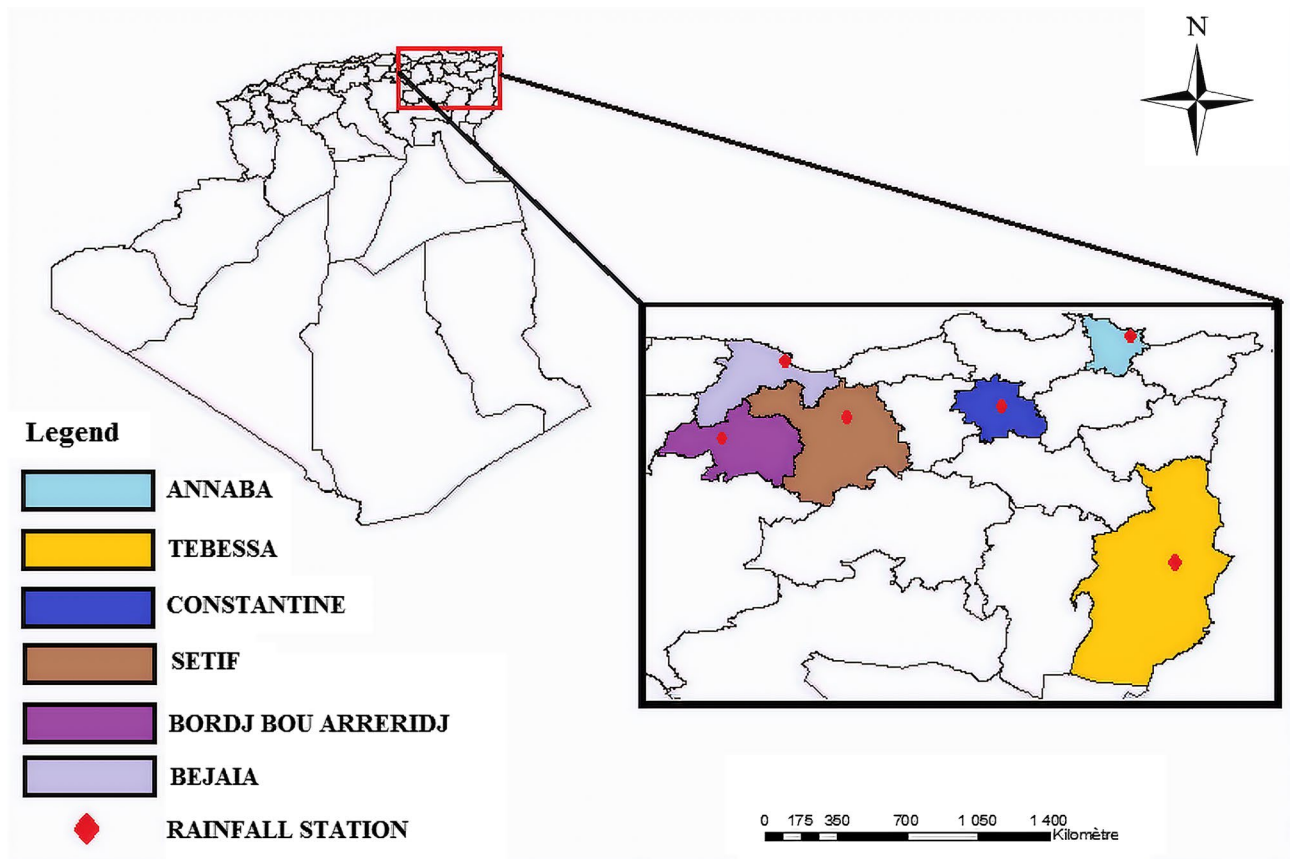


Fig. 1 Study area and observation station locations

Table 1 Observation stations and related information

Station name	Code of the station	Latitude (m)	Longitude (m)	Altitude (m)	Name of watershed	Area of the province (Km <sup>2</sup> )	Population
Annaba	603,600 (DABB)	36.83	7.81	4	(03) Constantine Coastal East	1439	640,050
Constantine	604190 (DABC)	36.28	6.61	694	(10) Kebir Rhumel	2197	943,112
Bejaia	604020 (DAAE)	36.71	5.04	2	(1510) Soummam	3268	915,835
Setif	604450 (DAAS)	36.18	5.41	1038	(1506) Soummam	6504	1,496,150
Tebessa	604750 (DABS)	35.41	8.13	813	(12) Megjerda Mellegue	14,227	657,227
Bordj-Bou-Argeridj	604440	36.06	4.76	930	(0509) El Hodna	3920	716,423

assessment and risk modeling ultimately benefits society by making it more resilient and saving lives, livelihoods and property.

In this paper, a general risk assessment procedure is implemented from a climate change perspective. Climate change is expected to affect all hydroclimatic variables at many different levels. Theoretically several convenient formulations have been generated for precipitation design values. Climate change effects are ignored in most calculation procedures. In water resource projects, risk levels are determined based on

the available methods which currently ignore climate change influence. In the classical approach, risk level is defined based on the frequency of damage occurrence. The simple definition of classical risk (*r*) suggested by (Kupper 2012) is as follows:

$$r = \frac{1}{R}, \tag{1}$$

where *R* is observed only once during the whole planned future life of any water structure. This simple risk approach

is modified by Şen et al. (2017) by taking into consideration the climate change effect as follows:

$$C_r = \frac{1 + \alpha}{R}, \tag{2}$$

where  $C_r$  is the risk under the climate change impact and  $\alpha$  is the slope of trend, and  $\alpha=0$  implies neither increasing or decreasing climate change occurrence. In other cases, climate change can be considered directly both as positive (increasing) and negative (decreasing) contributions to risk. In this methodology,  $\alpha$  is calculated as the slope of the trend within the hydrometeorological time series after normalization procedures are applied to the available data. The Matlab software was used to determine risk values based on different risk levels and cumulative distribution function (CDF curves) for each station.

### 4 Application

An extreme event is defined as the occurrence of a variable value above (or below) a threshold near the upper (or lower) ends of its observed range in a specific region.

The time series for each station with the trend component and corresponding CDF curves for exceedance probability calculations are presented in a set of figures for precipitation and temperature records. For instance, Annaba station trend and risk graphs are presented in Fig. 2.

The figures show a negative trend for temperature and positive trend for precipitation, but neither trend is significant compared to the variability in the series. There is a noticeable difference between the temperature and precipitation results. For example, the temperature trend graph has a shift each 10-year interval from below (above) average while the precipitation trend graph remains unstable throughout the time period, especially, during the period between 1995

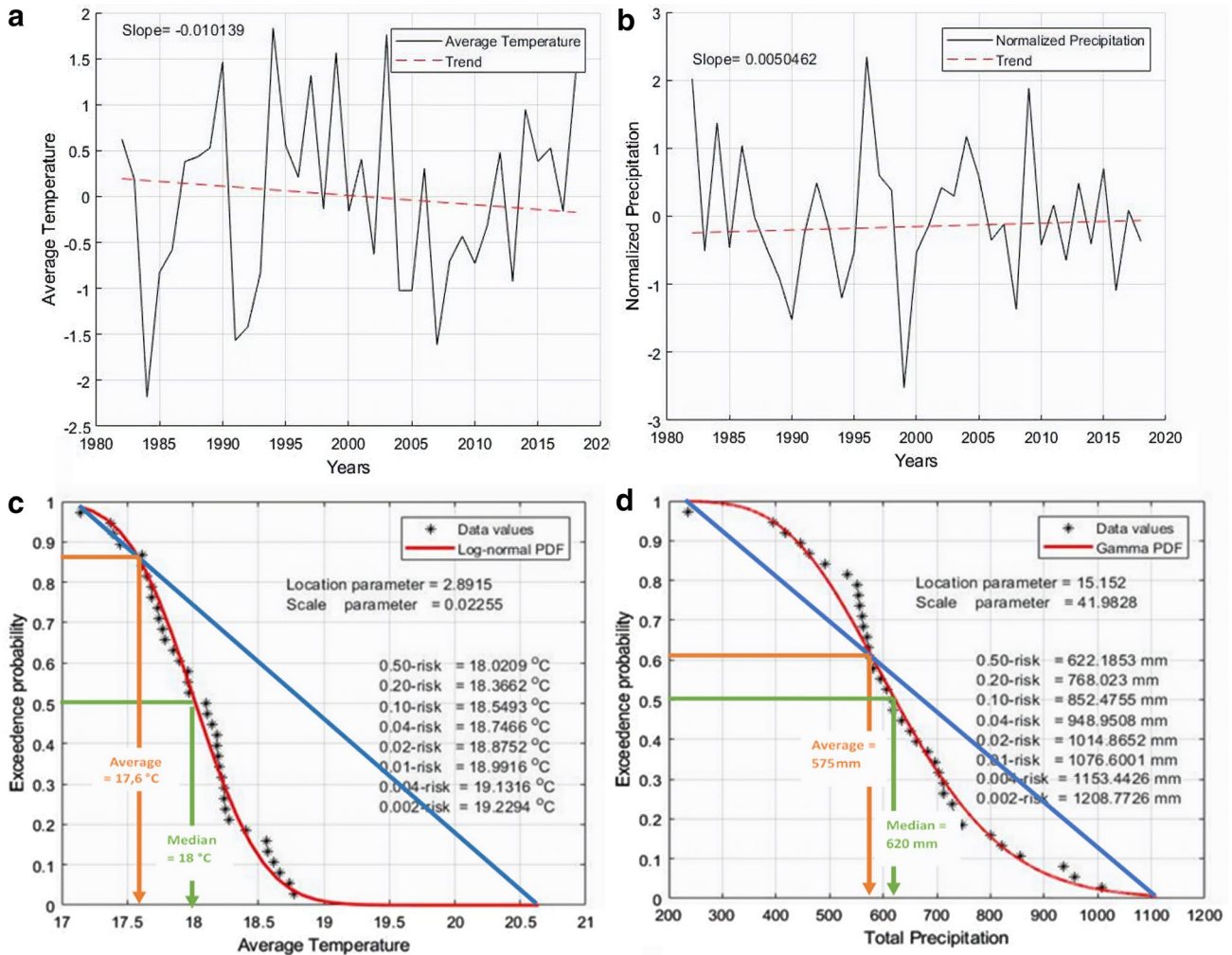


Fig. 2 Trends and CDF curves for Annaba Station. **a** Temperature, **b** precipitation, **c** temperature CDF, and **d** precipitation CDF



and 2000 which shows dramatic variation between successive years.

The straight line plot from minimum to maximum of the temperature CDF curve reveals a high kurtosis, with higher probability of extreme events occurring at the right-hand tail representing high temperatures. The area below the line is greater than above indicating a negative skew (median > average), with more than the half of daily temperatures (86% of the time series) exceeding the average. The precipitation CDF curve does not show high kurtosis, the area below the straight line from maximum to minimum is greater than above, indicating negative skew (median > average), 60% of the time series exceeds the average with 10% of the series reaching very extreme levels between 850 mm to more than 1100 mm.

Bejaia station analysis results are presented in Fig. 3. As for temperature, there is a positive trend in precipitation but this is of less significance. Additionally, one can also observe the variability in precipitation records alone. The temperature records are notably more regular except for 2006 where there is large variation. The temperature CDF curve reveals very high kurtosis implying a very high

probability of extreme events in the tails of the distribution. As previously, the area below the straight line from minimum to maximum is greater than above, indicating negative skew (median > average) with a very large proportion of the time series (96%) exceeding the average. Finally, the precipitation CDF curve shows a higher standard deviation (implying a high level of dispersion and risk). The area below the max–min straight line is greater than above, indicating negative skew (median > average), 75% of days received greater precipitation than average, with only 10% of the results regarded as extremes between 1000 and 1500 mm.

Bordj-Bouarridj station analysis results are presented in Fig. 4 and show a negative trend for temperature and a positive trend for precipitation. Variability exists in both parameters but in different ways. Temperatures are increased at the same rate until 2013 but then increased much more rapidly, whereas precipitation varied significantly in the early years but then stabilized with time. For temperature, the CDF curve has a high kurtosis with high probability of extreme events occurring in the tail of the distribution. In both cases, the right tail represents very high temperatures with the area below the line exceeding that above, indicating

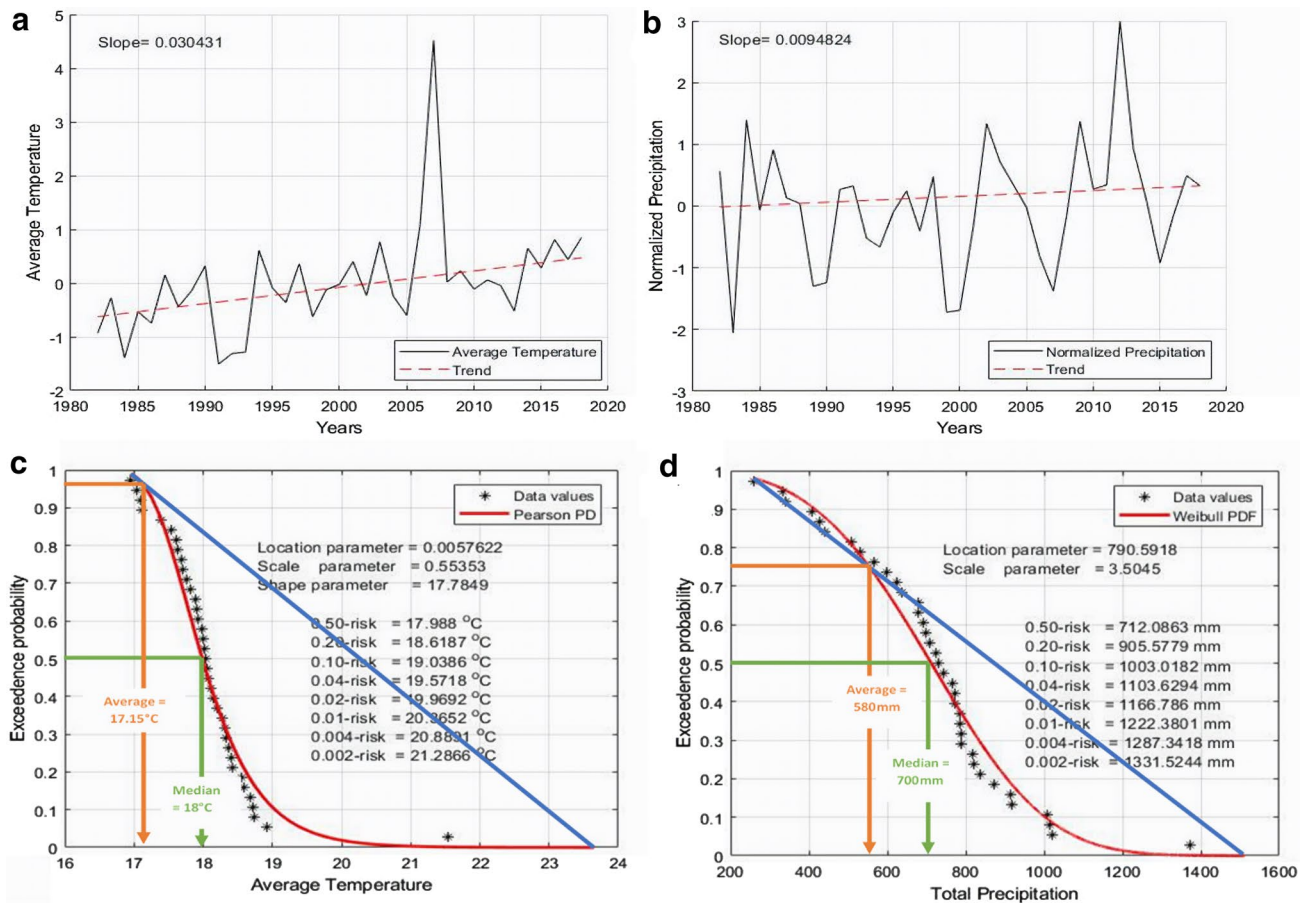
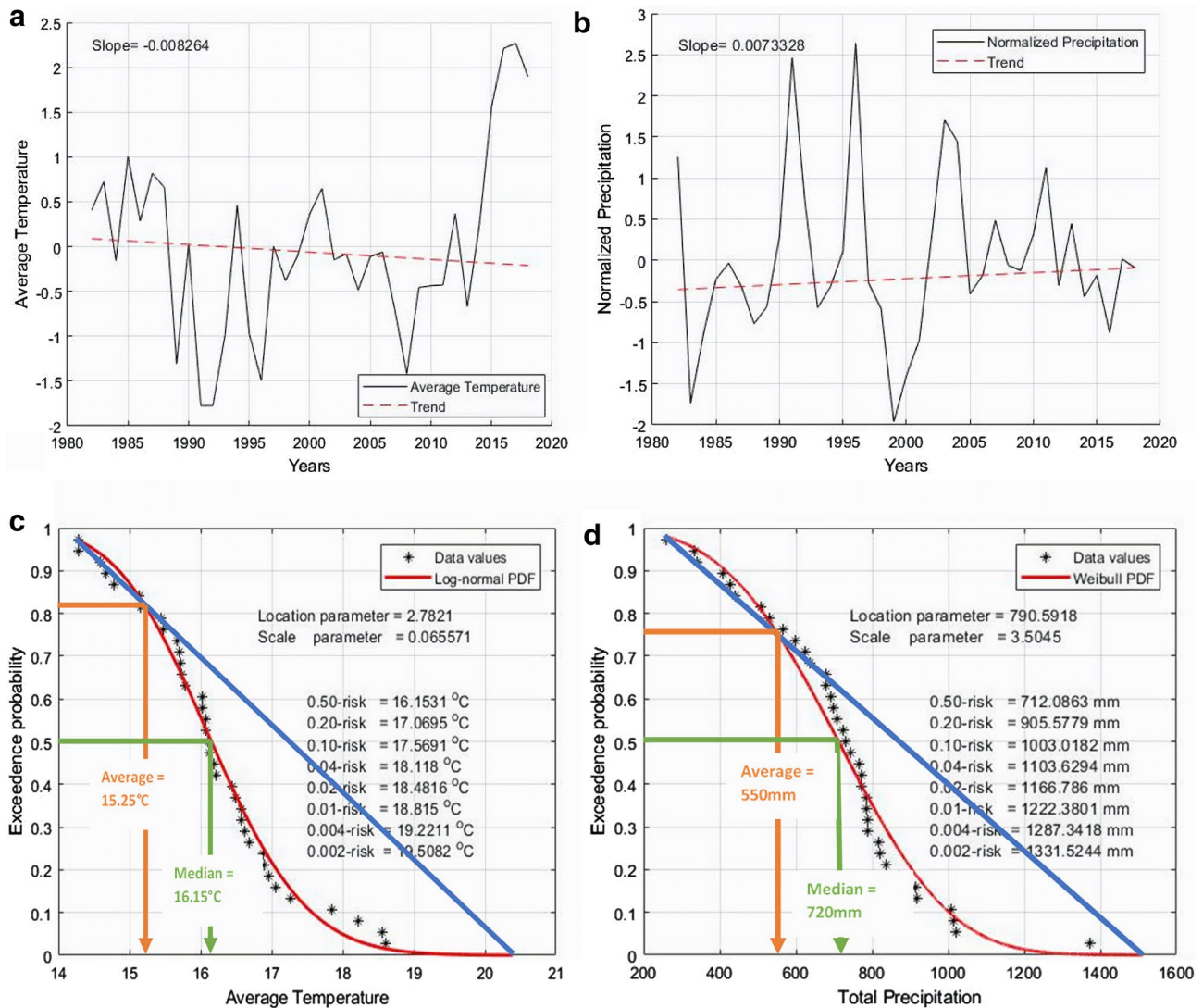


Fig. 3 Trends and CDF curves for Bejaia Station. **a** Temperature, **b** precipitation, **c** temperature CDF, and **d** precipitation CDF



**Fig. 4** Trends and CDF curves for Bordj-Bouarriridj Station. **a** Temperature, **b** precipitation, and **c** temperature CDF

negative skew (median > average); 82% of each day's temperatures are above the average, 5% exceed 18 °C to a maximum of 20 °C. For precipitation, the CDF plot is flat with higher standard deviation (dispersion and risk). Again, the area below the line is greater than that above, indicating a negative skew (median > average), on 76% of days the average was exceeded, with 10% of results reaching the extremes of between 1000 and 1500 mm.

Figure 5 shows the results for Constantin station. There is a significant positive trend for temperature with the large variability stabilizing with time. However, precipitation trends negatively with minor significance but high variability remains for the full time series. While CDF curves reveals that almost three quarters of days were hotter and wetter than average and 20% were considered as extremely rainy days.

Figure 6 depicts the Setif station analysis results. Both temperature and precipitation have a positive trend at a slope equal to 0.03 and variability increasing from 1990 to 2005. Both CDF curves reveal normal distributions since there is no kurtosis—the median equals the average. Less than 5% of this time series showed extreme results.

Tebessa station represents a significant positive trend in temperature with moderate variability; on the other hand, precipitation illustrates a minor positive trend with major variability. CDF curves reveal that 75% of time series of temperature, and 87% of received precipitation were above the average, where 10% of those days reached extreme levels (Fig. 7).

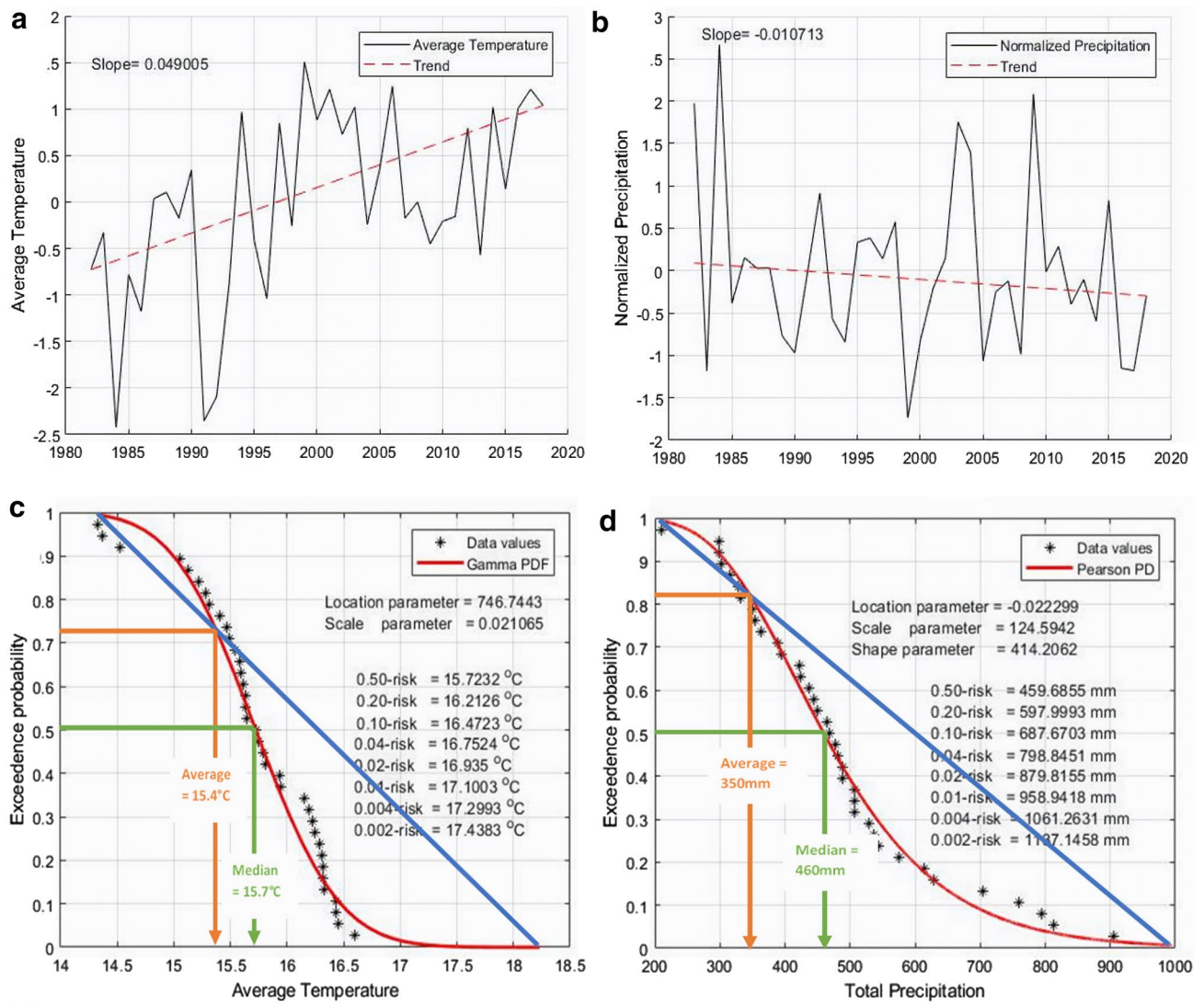


Fig. 5 Trends and CDF curves for Constantine Station. **a** Temperature, **b** precipitation, and **c** temperature

### 5 Results and Discussion

Before any infrastructure construction, risk assessment and return period (or average frequency of occurrence) should be assessed and taken into consideration. The classical risk is the probability of dangerous event occurrence only once during the entire life of the infrastructure. In this paper, it is proposed that the risk calculations should additionally be based on the slope of possible trends in temperature and precipitation records over the life span.

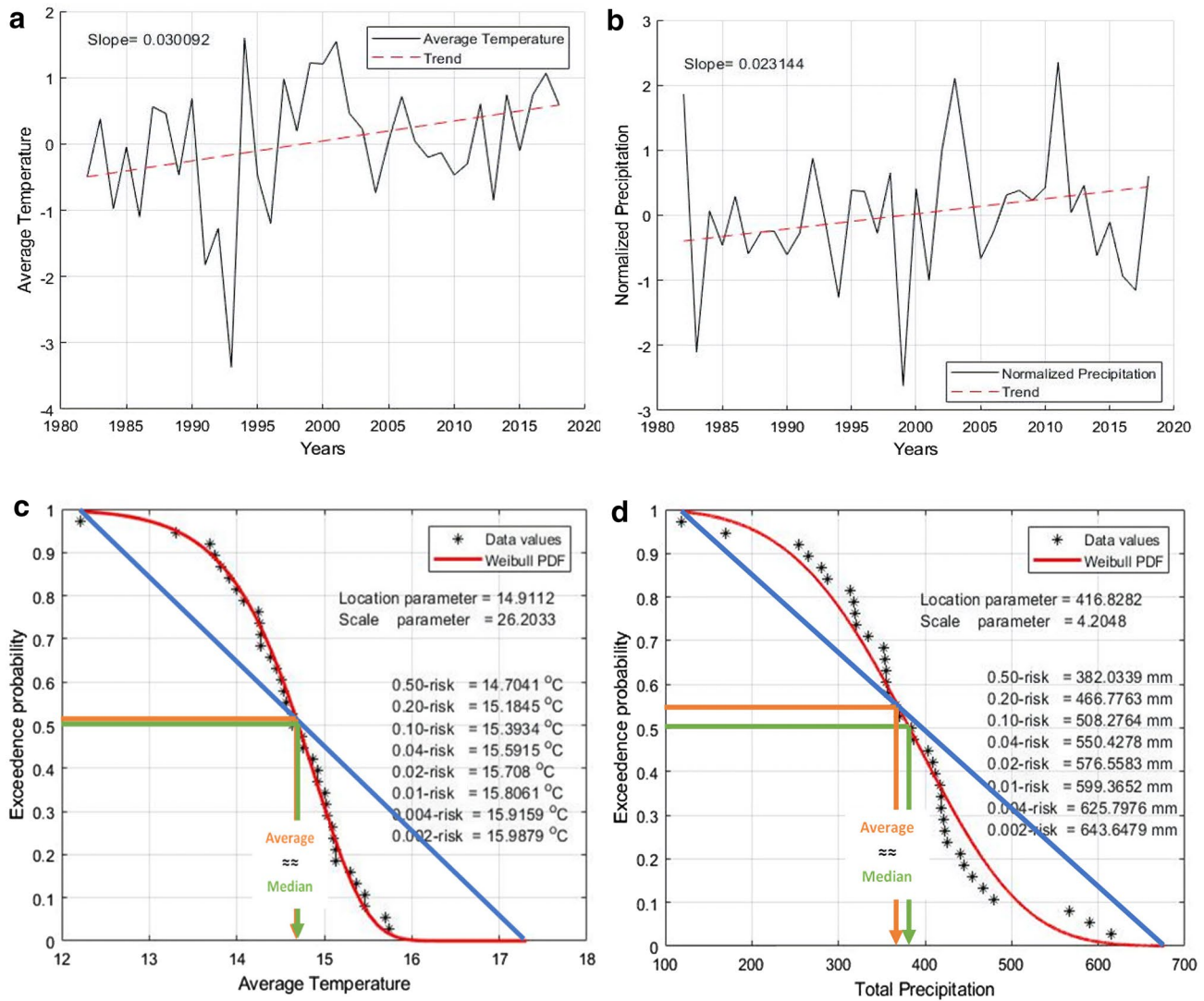
To calculate the risk under climate change effects, a climate factor  $\alpha$  (the slope of the trend component within the hydrometeorological time series) needs to be added to the numerator of the classical risk formula. If  $\alpha=0$ , there is no climate change variation trend, otherwise  $\alpha$  takes positive (increasing) and negative (decreasing) values.

Tables 2 and 3 represent the annual precipitation records at each meteorological station and the statistics of both cases with and without climate change effect for different return periods. The relative error,  $\beta$ , is calculated by taking into consideration precipitation (or temperature) levels under the effects of climate change  $C_{cc}$  and with no climate effect,  $P$ , according to the following expression:

$$\beta = 100 \left( \frac{C_{cc} - P}{C_{cc}} \right). \tag{3}$$

Concerning the precipitation parameter, Table 2, note that Setif and Tébessa stations present the higher positive levels of relative error percentage mean that the impact of climate change on these two stations is more severe than





**Fig. 6** Trends and CDF curves for Setif Station. **a** Temperature, **b** precipitation, and **c** temperature CDF

for the others, followed by Bejaia and Bordj-Bouarriridj station with least affect for Annaba station.

All stations show increasing precipitation. However, Constantine station presents a negative relative error percentage reflecting decreasing precipitation under climate change effect while all other stations show an increasing effect.

Table 3 shows the results appropriate for temperature. The  $\beta$  value for Annaba and Bordj-Bouarriridj stations during all return periods has a negative sign ( $-$ ), which means that these two stations are subject to lower annual average temperature, whereas other stations, namely Tebessa, Constantine, Setif and Bejaia have positive  $\beta$ , implying that climate change will increase their temperatures with Tebessa increasing most.

After calculating climate change risk level from Eq. (2), one can use Eq. (1) to find the new return period,

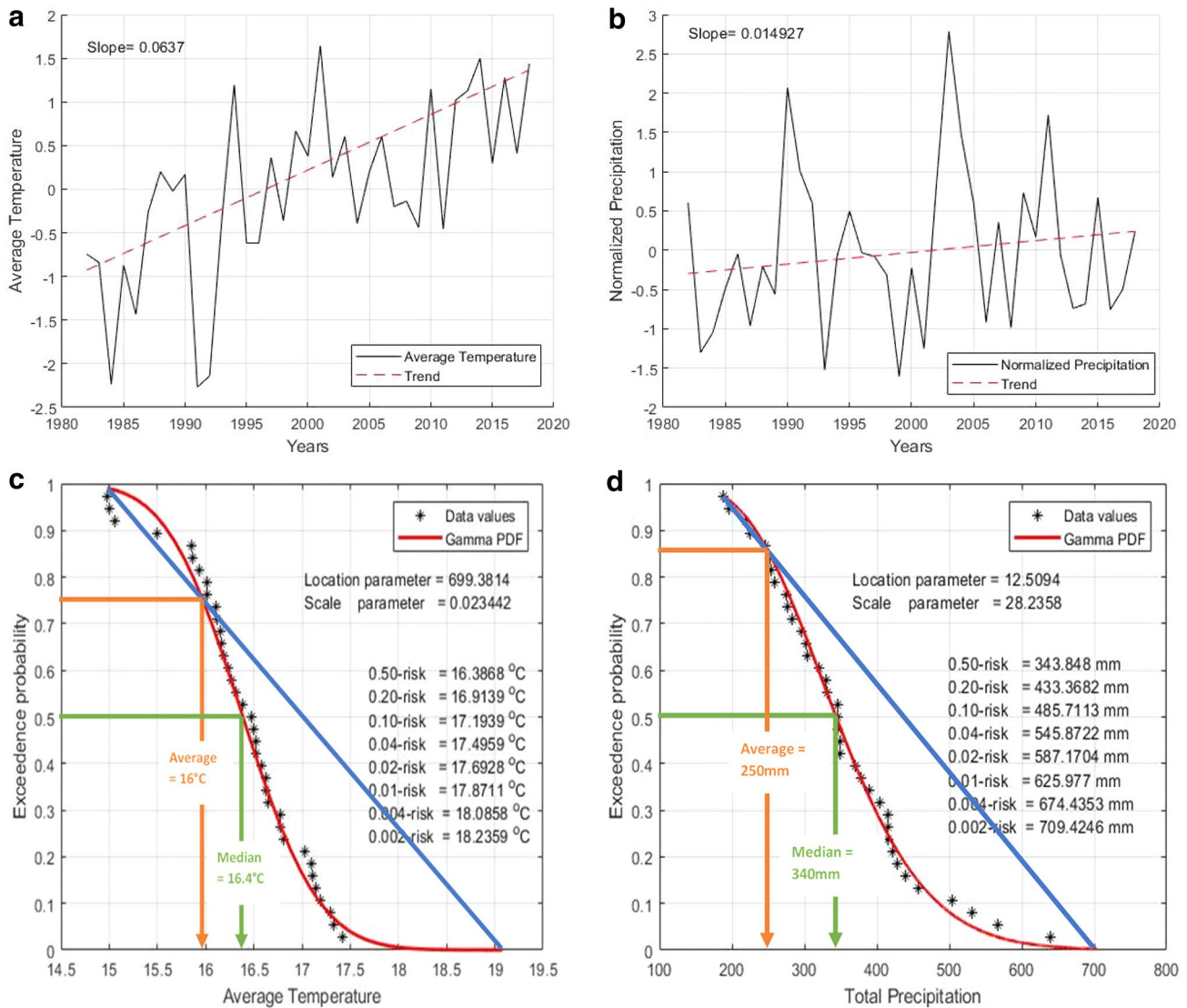
incorporating the climate change effect. For this case, the relative error percentage ( $\gamma$ ) is calculated similar to Eq. (3) as

$$\gamma = 100 \left( \frac{C_R - R}{C_R} \right), \quad (4)$$

where  $C_R$  and  $R$  are the return periods with and without climate change effect, respectively, leading to results in Tables 4 and 5.

Table 4 reveals that only Constantine station has a positive relative error percentage ( $\gamma$ ), which means that the return period for extreme levels of precipitation including climate change considerations is longer than without climate change impact. The greater the return period increase, the longer it extends. In contrast, at the other five





**Fig. 7** Trends and CDF curves for Tebessa Station. **a** Temperature, **b** precipitation, **c** temperature CDF, and **d** precipitation CDF

stations, shorter return periods prevail implying that rare events will occur faster due to climate change.

Table 5 expresses the return periods including climate change impacts. Annaba and Borj-Bouarridj stations expect longer return periods, while Tebessa, Constantine, Bejaia and Setif anticipate shorter return periods for extreme temperature occurrence.

### 6 Conclusion

It is well known that precipitation and temperature have been steadily increasing all around the world, and especially, in the Mediterranean basin over the last 3 decades. The most important concept in any water resource system design is the risk associated with hydrometeorological events. The

purpose of this study is to analyze trends in temperature and precipitation records and incorporate these into risk assessments by incorporating the changing climate (temperature and precipitation) for the Northeast of Algeria over the 35-year period (1982–2017). For this purpose, a climate change factor is incorporated into the classical formulation, based on the trend slope in historical records. The risks associated with 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year return periods are calculated for each station. The study indicates that climate change impact is expected to be more influential at all locations except Constantine where the risk of extreme precipitation appears likely to diminish. Temperatures in Tebessa, Constantine, Setif and Bejaia are expected to reach more frequent extremes.

Infrastructure that has been planned for construction in Annaba, Tebessa, Bejaia, Borj-Bouarridj and Setif that use

**Table 2** Climate impact on precipitation features

Return period	Cities	Annaba	Tebessa	Constantine	Bejaia	Borj-Bouarriridj	Setif
2 years	Climate factor for precipitation ( $\alpha$ )	0.005	0.015	- 0.011	0.009	0.007	0.064
	Risk $C_r$ for precipitation	0.503	0.507	0.495	0.505	0.504	0.532
	Precipitation (mm) with climate change into consideration ( $C_p$ )	623.206	345.690	457.780	714.866	329.024	385.064
	Precipitation (mm) without climate change ( $P$ )	622.185	343.848	459.686	712.086	327.971	382.034
	Relative error (%) $\beta$	0.164	0.533	- 0.416	0.389	0.320	0.787
5 years	Risk $C_r$ for precipitation	0.201	0.203	0.198	0.202	0.201	0.213
	Precipitation (mm) with climate change into consideration ( $C_p$ )	768.693	434.597	596.560	907.104	434.552	468.382
	Precipitation (mm) without climate change ( $P$ )	768.023	433.368	597.999	905.578	433.830	466.776
	Relative error (%) $\beta$	0.087	0.283	- 0.241	0.168	0.166	0.343
10 years	Risk $C_r$ for precipitation	0.101	0.101	0.099	0.101	0.101	0.106
	Precipitation (mm) with climate change into consideration ( $C_p$ )	853.048	486.768	686.338	1004.201	497.461	509.501
	Precipitation (mm) without climate change ( $P$ )	852.475	485.711	687.670	1003.018	496.837	508.276
	Relative error (%) $\beta$	0.067	0.217	- 0.194	0.118	0.125	0.240
25 years	Risk $C_r$ for precipitation	0.040	0.041	0.040	0.040	0.040	0.043
	Precipitation (mm) with climate change into consideration ( $C_p$ )	949.450	546.801	797.583	1104.561	569.736	551.377
	Precipitation (mm) without climate change ( $P$ )	948.951	545.872	798.845	1103.629	569.193	550.428
	Relative error (%) $\beta$	0.053	0.170	- 0.158	0.084	0.095	0.172
50 years	Risk $C_r$ for precipitation	0.020	0.020	0.020	0.020	0.020	0.021
	Precipitation (mm) with climate change into consideration ( $C_p$ )	1015.329	588.036	878.586	1167.596	618.587	577.377
	Precipitation (mm) without climate change ( $P$ )	1014.865	587.170	879.816	1166.786	618.091	576.558
	Relative error (%) $\beta$	0.046	0.147	- 0.140	0.069	0.080	0.142
100 years	Risk $C_r$ for precipitation	0.010	0.010	0.010	0.010	0.010	0.011
	Precipitation (mm) with climate change into consideration ( $C_p$ )	1077.038	626.796	957.737	1223.101	663.398	600.089
	Precipitation (mm) without climate change ( $P$ )	1076.600	625.977	958.942	1222.380	662.942	599.365
	Relative error (%) $\beta$	0.041	0.131	- 0.126	0.059	0.069	0.121
250 years	Risk $C_r$ for precipitation	0.004	0.004	0.004	0.004	0.004	0.004
	Precipitation (mm) with climate change into consideration ( $C_p$ )	1153.854	675.208	1060.087	1287.975	717.272	626.428
	Precipitation (mm) without climate change ( $P$ )	1153.443	674.435	1061.263	1287.342	716.862	625.798
	Relative error (%) $\beta$	0.036	0.114	- 0.111	0.049	0.057	0.101
500 years	Risk $C_r$ for precipitation	0.002	0.002	0.002	0.002	0.002	0.002
	Precipitation (mm) with climate change into consideration ( $C_p$ )	1209.169	710.170	1135.989	1332.107	754.410	644.224
	Precipitation (mm) without climate change ( $P$ )	1208.773	709.425	1137.146	1331.524	754.031	643.648
	Relative error (%) $\beta$	0.033	0.105	- 0.102	0.044	0.050	0.089

The higher the number of return periods, the lower the relative error percentage value

precipitation data should take into consideration the impact of climate change on extreme weather return periods. In the same light, the temperature data considerations should follow the same approach for Tebessa, Constantine, Bejaia and Setif cities.

Positive trends in temperature and precipitation records appear in most stations with varying degrees. For example, in Constantine and Tebessa, a significantly increasing trend for temperature is indicated with a slope 0.05, while Bejaia and Setif have less significant trends with

**Table 3** Climate impact on temperature features

Return period	Cities	Annaba	Tebessa	Constantine	Bejaia	Borj-Bouarriridj	Setif
2 years	Climate factor for temperature ( $\alpha$ )	- 0.010	0.064	0.049	0.030	- 0.008	0.023
	Risk $C_r$ for temperature	0.495	0.532	0.525	0.515	0.496	0.512
	Temperature (C°) with climate change into consideration (Ct)	18.016	16.436	15.759	18.012	16.142	14.728
	Temperature(C°) without climate change (T)	18.021	16.387	15.723	17.988	16.153	14.704
	Relative error (%) $\beta$	- 0.029	0.302	0.225	0.136	- 0.068	0.164
5 years	Risk $C_r$ for temperature	0.198	0.213	0.210	0.206	0.198	0.205
	Temperature (C°) with climate change into consideration (Ct)	18.363	16.943	16.233	18.638	17.063	15.195
	Temperature(C°) without climate change (T)	18.366	16.914	16.213	18.619	17.070	15.184
10 years	Relative error (%) $\beta$	- 0.016	0.174	0.129	0.104	- 0.039	0.072
	Risk $C_r$ for temperature	0.099	0.106	0.105	0.103	0.099	0.102
	Temperature (C°) with climate change into consideration (Ct)	18.547	17.218	16.489	19.057	17.564	15.401
25 years	Temperature(C°) without climate change (T)	18.549	17.194	16.472	19.039	17.569	15.393
	Relative error (%) $\beta$	- 0.013	0.138	0.102	0.096	- 0.031	0.050
	Risk $C_r$ for temperature	0.040	0.043	0.042	0.041	0.040	0.041
50 years	Temperature (C°) with climate change into consideration (Ct)	18.745	17.516	16.766	19.590	18.113	15.597
	Temperature(C°) without climate change (T)	18.747	17.496	16.752	19.572	18.118	15.591
	Relative error (%) $\beta$	- 0.011	0.112	0.083	0.091	- 0.025	0.036
100 years	Risk $C_r$ for temperature	0.020	0.021	0.021	0.021	0.020	0.020
	Temperature (C°) with climate change into consideration (Ct)	18.873	17.710	16.947	19.987	18.478	15.713
	Temperature(C°) without climate change (T)	18.875	17.693	16.935	19.969	18.482	15.708
250 years	Relative error (%) $\beta$	- 0.009	0.100	0.074	0.088	- 0.022	0.030
	Risk $C_r$ for temperature	0.010	0.011	0.010	0.010	0.010	0.010
	Temperature (C°) with climate change into consideration (Ct)	18.990	17.887	17.112	20.383	18.811	15.810
500 years	Temperature(C°) without climate change	18.992	17.871	17.100	20.365	18.815	15.806
	Relative error (%) $\beta$	- 0.009	0.090	0.067	0.087	- 0.020	0.025
	Risk $C_r$ for temperature	0.004	0.004	0.004	0.004	0.004	0.004
500 years	Temperature (C°) with climate change into consideration (Ct)	19.130	18.100	17.310	20.907	19.218	15.919
	Temperature(C°) without climate change (T)	19.132	18.086	17.299	20.889	19.221	15.916
	Relative error (%) $\beta$	- 0.008	0.081	0.060	0.085	- 0.018	0.021
500 years	Risk $C_r$ for temperature	0.002	0.002	0.002	0.002	0.002	0.002
	Temperature (C°) with climate change into consideration (Ct)	19.228	18.250	17.448	21.304	19.505	15.991
	Temperature(C°) without climate change (T)	19.229	18.236	17.438	21.287	19.508	15.988
	Relative error (%) $\beta$	- 0.007	0.075	0.056	0.083	- 0.017	0.019

The higher the number of return periods, the lower the relative error percentage value

0.03 slopes. Additionally, Annaba and Bordj-Bouarriridj show a decreasing, but not significant trend. As for the precipitation records, all stations indicate positive, but not significant trends, except Constantine station which

tends to decrease with little significance. The cumulative distribution function (CDF) curves reveal that Annaba, Bejaia, Borj-Bouarriridj, Constantine and Tebessa have more than 70% of their days being hotter and wetter than

**Table 4** Return period (year) comparison for precipitations

Return period	Cities	Annaba	Tebessa	Constantine	Bejaia	Borj-Bouarridj	Setif
2 years	Climate change risk $C_r$ for precipitation	0.503	0.507	0.495	0.505	0.504	0.532
	Climate change return period “new return period”	1.990	1.971	2.022	1.981	1.985	1.880
	Difference = return period under climate change effect – return period without climate change	– 0.010	– 0.029	0.022	– 0.019	– 0.015	– 0.120
	Relative error (%) $\gamma$	– 0.505	– 1.493	1.071	– 0.948	– 0.733	– 6.370
5 years	Climate change risk $C_r$ for precipitation	0.201	0.203	0.198	0.202	0.201	0.213
	Climate change return period “new return period”	4.975	4.926	5.054	4.953	4.964	4.701
	Difference = return period under climate change effect – return period without climate change	– 0.025	– 0.074	0.054	– 0.047	– 0.036	– 0.299
	Relative error (%) $\gamma$	– 0.505	– 1.493	1.071	– 0.948	– 0.733	– 6.370
10 years	Climate change risk $C_r$ for precipitation	0.101	0.101	0.099	0.101	0.101	0.106
	Climate change return period “new return period”	9.950	9.853	10.108	9.906	9.927	9.401
	Difference = return period under climate change effect – return period without climate change	– 0.050	– 0.147	0.108	– 0.094	– 0.073	– 0.599
	Relative error (%) $\gamma$	– 0.505	– 1.493	1.071	– 0.948	– 0.733	– 6.370
25 years	Climate change risk $C_r$ for precipitation	0.040	0.041	0.040	0.040	0.040	0.043
	Climate change return period “new return period”	24.874	24.632	25.271	24.765	24.818	23.503
	Difference = return period under climate change effect – return period without climate change	– 0.126	– 0.368	0.271	– 0.235	– 0.182	– 1.497
	Relative error (%) $\gamma$	– 0.505	– 1.493	1.071	– 0.948	– 0.733	– 6.370
50 years	Climate change risk $C_r$ for precipitation	0.020	0.020	0.020	0.020	0.020	0.021
	Climate change return period “new return period”	49.749	49.265	50.541	49.530	49.636	47.006
	Difference = return period under climate change effect – return period without climate change	– 0.251	– 0.735	0.541	– 0.470	– 0.364	– 2.994
	Relative error (%) $\gamma$	– 0.505	– 1.493	1.071	– 0.948	– 0.733	– 6.370
100 years	Climate change risk $C_r$ for Precipitation	0.010	0.010	0.010	0.010	0.010	0.011
	Climate change return period “new return period”	99.498	98.529	101.083	99.061	99.272	94.011
	Difference = return period under climate change effect – return period without climate change	– 0.502	– 1.471	1.083	– 0.939	– 0.728	– 5.989
	Relative error (%) $\gamma$	– 0.505	– 1.493	1.071	– 0.948	– 0.733	– 6.370
250 years	Climate change risk $C_r$ for precipitation	0.004	0.004	0.004	0.004	0.004	0.004
	Climate change return period “new return period”	248.745	246.323	252.707	247.652	248.180	235.029
	Difference = return period under climate change effect – return period without climate change	– 1.255	– 3.677	2.707	– 2.348	– 1.820	– 14.971
	Relative error (%) $\gamma$	– 0.505	– 1.493	1.071	– 0.948	– 0.733	– 6.370
500 years	Climate change risk $C_r$ for precipitation	0.002	0.002	0.002	0.002	0.002	0.002
	Climate change return period “new return period”	497.490	492.646	505.415	495.303	496.360	470.057
	Difference = return period under climate change effect – return period without climate change	– 2.510	– 7.354	5.415	– 4.697	– 3.640	– 29.943
	Relative error (%) $\gamma$	– 0.505	– 1.493	1.071	– 0.948	– 0.733	– 6.370

average with only the Setif station having equally likely temperatures and precipitations above and below the average. This study confirms that climate change has and will

continue to have impacts on temperature and precipitation and should be taken into consideration in the calculations of all infrastructure constructions.



**Table 5** Return period (year) comparison for temperatures

Return period	Cities	Annaba	Tebessa	Constantine	Bejaia	Borj-Bouarridj	Setif
2 years	Climate change risk $C_r$ for temperature	0.495	0.532	0.525	0.515	0.496	0.512
	Climate change return period “new return period”	2.020	1.880	1.907	1.941	2.017	1.955
	Difference = return period under climate change effect – return period without climate change	0.020	– 0.120	– 0.093	– 0.059	0.017	– 0.045
	Relative error (%) $\gamma$	1.014	– 6.370	– 4.901	– 3.043	0.826	– 2.314
5 years	Climate change risk $C_r$ for temperature	0.198	0.213	0.210	0.206	0.198	0.205
	Climate change return period “new return period”	5.051	4.701	4.766	4.852	5.042	4.887
	Difference = return period under climate change effect – return period without climate change	0.051	– 0.299	– 0.234	– 0.148	0.042	– 0.113
	Relative error (%) $\gamma$	1.014	– 6.370	– 4.900	– 3.043	0.826	– 2.314
10 years	Climate change risk $C_r$ for temperature	0.099	0.106	0.105	0.103	0.099	0.102
	Climate change return period “new return period”	10.102	9.401	9.533	9.705	10.083	9.774
	Difference = return period under climate change effect – return period without climate change	0.102	– 0.599	– 0.467	– 0.295	0.083	– 0.226
	Relative error (%) $\gamma$	1.014	– 6.370	– 4.900	– 3.043	0.826	– 2.314
25 years	Climate change risk $C_r$ for temperature	0.040	0.043	0.042	0.041	0.040	0.041
	Climate change return period “new return period”	25.256	23.503	23.832	24.262	25.208	24.434
	Difference = return period under climate change effect – return period without climate change	0.256	– 1.497	– 1.168	– 0.738	0.208	– 0.566
	Relative error (%) $\gamma$	1.014	– 6.370	– 4.901	– 3.043	0.826	– 2.314
50 years	Climate change risk $C_r$ for temperature	0.020	0.021	0.021	0.021	0.020	0.020
	Climate change return period “new return period”	50.512	47.006	47.664	48.523	50.417	48.869
	Difference = return period under climate change effect – return period without climate change	0.512	– 2.994	– 2.336	– 1.477	0.417	– 1.131
	Relative error (%) $\gamma$	1.014	– 6.370	– 4.901	– 3.043	0.826	– 2.314
100 years	Climate change Risk $C_r$ for temperature	0.010	0.011	0.010	0.010	0.010	0.010
	Climate change return period “new return period”	101.024	94.011	95.328	97.047	100.833	97.738
	Difference = return period under climate change effect – return period without climate change	1.024	– 5.989	– 4.672	– 2.953	0.833	– 2.262
	Relative error (%) $\gamma$	1.014	– 6.370	– 4.901	– 3.043	0.826	– 2.314
250 years	Climate change risk $C_r$ for temperature	0.004	0.004	0.004	0.004	0.004	0.004
	Climate change return period “new return period”	252.561	235.029	238.321	242.617	252.083	244.345
	Difference = return period under climate change effect – return period without climate change	2.561	– 14.971	– 11.679	– 7.383	2.083	– 5.655
	Relative error (%) $\gamma$	1.014	– 6.370	– 4.901	– 3.043	0.826	– 2.314
500 years	Climate change risk $C_r$ for temperature	0.002	0.002	0.002	0.002	0.002	0.002
	Climate change return period “new return period”	505.121	470.057	476.642	485.234	504.166	488.690
	Difference = return period under climate change effect – return period without climate change	5.121	– 29.943	– 23.358	– 14.766	4.166	– 11.310
	Relative error (%) $\gamma$	1.014	– 6.370	– 4.901	– 3.043	0.826	– 2.314

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