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Heat waves in Algeria: A potential risk

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Abstract:

Algeria, which is located in a transition zone between the temperate and subtropical systems, is highly sensitive to climate. It is exposed to extreme events such as floods, prolonged droughts and more recently heat waves. The thermal characterization is subjective because it depends on the sensitivity of a person. In the literature, there is not a universal definition to characterize the heat wave and the peak of heat.

Our contribution focused on the analysis of air temperature data in Algeria, through the calculation of the average thermal amplitude of the warm season (from June to September)"difference between the maximum temperature (MaxT) and the minimum temperature (MinT)", taking into account 16 main meteorological stations distributed throughout the entire national territory over a time span of 28 years (1988-2015.)

Despite the fact that MaxT and MinT have not increased significantly except in Tamanrasset station (only for MaxT), however, it generally appears that the difference between maximum and minimum temperatures has widened during the warm period (June, July, August and September).

For a contribution to the study about heat waves we chose the Algerian Sahara, through six stations. To define a day of intense heat, we take the northern Sahara, the daily maximum temperature was (MaxT) $\geqslant$ 42.5 ° C and the minimum (MinT) $\geqslant$ 27.5 ° C. For the central Sahara, we consider the following thresholds: MaxT $\geqslant$ 47.5 ° C and MinT $\geqslant$ 30 ° C. We identify two separate periods within the six stations 1951-1980 and 1981-2010; the choice of these two periods was determined from the findings of various studies on climate and climate change. Indeed, statistical tests applied to the long series of temperatures show a break in stationary condition at the end of seventy years.

The thermal amplitude varied between 9 °C and 15 °C in the littoral and between 10 °C and 20 °C in the highlands and the Sahara.

It appears that in general the number of hot days has seen a rising trend. Heat sequences have become longer and more frequent in the last two decades in step with global warming. Considering higher or equal sequences to 3 days (definition of the heat wave), the number of observed cases was a growth rate above 100%. The study also indicates a lengthening of the warm period.

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1. Introduction

Climate change is a dynamic result between a series of different factors (natural and anthropogenic) where the contribution depends mainly on the importance of their actions over time (Chourghal, 2016).

The global average temperature of the planet is increasing. However, certain regions could cool down rather than warm up. Thus, the term "climate change" is now more widely used to describe the phenomenon (Vachon, 2016).

According to the Algerian National Institute for Agricultural Research (INRA Algérie, 2016), the global average surface temperature has largely broken all records in 2015. For the first time, temperatures have exceeded 1 °C those of pre-industrial period, based on an analysis of the World Meteorological Organization (WMO), which relies on reference data.

Over this century we have 15 of the 16 warmest years. 2016 has experienced the highest temperatures compared to the records of 2015. The five-year periods 2011-2015 confirm this long-term trend and have probably been the warmest years on record.

Heat waves cause or are favorable to create more disturbances to society, we note, for instance:

- In addition to the congestion in hospitals, they have an adverse effect on human health, especially for older people and babies,
- Over-consumption of water (especially drinking water),
- Energy overconsumption (demand higher than supply especially in summer and unsuitable building types that require the air conditioning use),
- Decline in agricultural production,
- Forest fires (favorable climate for triggering),
- Work stoppages at construction sites ...etc.

The forecasts show that the southern area of the Mediterranean basin is one of the most exposed areas to global warming (Chourghal, 2016).

In Algeria, the number of warm days and heat waves increased from the early 1990s (Faci, 2016 a).

This contribution is part of a cooperation project between the Center for Scientific and Technical Research on Arid Regions (CRSTRA, Biskra, Algeria) and the Euro-Mediterranean Agreement on Major Hazards.

2. Data and method

2.1. Thermal amplitude

2.1.1. Data

The air temperature data related to the monthly average of maximum and minimum temperatures were identified by the main stations of the National Office of Meteorology (ONM, 2015) cover the period 1988-2015.

The scope of this study is limited to the average temperature of the warmest four months during the year (June, July, August and September).

2.1.2. Stations

The data surveys are the maximum and minimum temperatures of sixteen (16) weather stations spread throughout the national territory (Figure 1), listed in Table 1.

Table 1. List of weather stations.

Number	The station name	Number	The station name
1	Annaba	**9**	El Oued
2	Algiers	**10**	Ghardaia
3	Oran	**11**	Béchar
4	Macheria	**12**	Tindouf
5	El-Bayadh	**13**	In Salah
6	Djelfa	**14**	In Amenas
7	Batna	**15**	Tamanrasset
8	Tébessa	**16**	In Guezzam

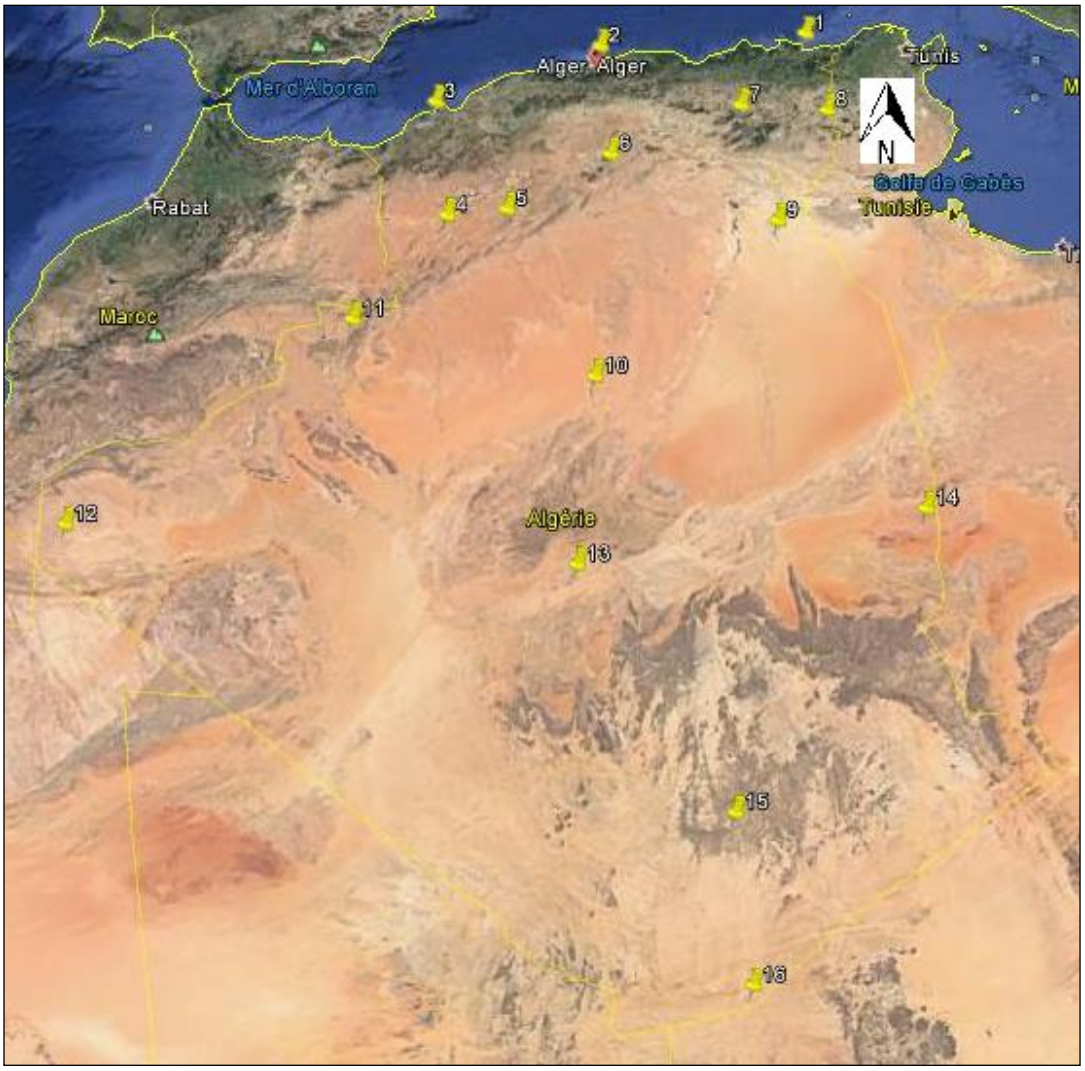

Figure 1. Location of weather stations on Algeria map.

2.1.3. Mann-Kendall trend test

The Mann-Kendall trend test has been used to analyse the various types of environmental data (McLeod, 1990). It allows us to examine the existence of a linear trend (up or down) based on time series (Braud, 2011).

2.1.4. Thermal amplitude

The thermal amplitude is the difference between the maximum temperature (MaxT) and the minimum temperature (MinT) (Bûche, 1995).

2.2. Heat waves

2.2.1. Stations

The Sahara is one of the largest deserts in the world. The present study is considered as a first in Algeria, we analyzed the weather data collected from six main stations (Figure 2) at the National Office of Meteorology in Algeria (ONM, 2010). These two stations are sub bioclimatic zones of Algeria, namely:

- Northern Sahara (Béchar, Biskra, Ghardaïa and Touggourt),
- The Central Sahara (Ain Salah and Timimoune).

Figure 2. Location of weather stations on the map of Algeria.

2.2.2. Periods

We examined a data set of minimum (MinT) and maximum temperatures (MaxT), this series was divided in two periods 1951-1980 and 1981-2010.

The choice of these two periods derived from the result of various studies on climate and global warming, for example, the work of Belarbi et *al* (2012) clearly shows a break in stationary in the late seventies.

2.2.3. Thresholds

The temperature thresholds depend on many factors including the type of climate, the sensitivity of the people and others. However, all scientists agree that it's a period of intense heat.

According to Hanchane et al (2016), a heat wave is a prolonged period of maximum temperatures at least six days exceeding the climatological standards by 5 °C.

For this survey, we took as threshold any temperature higher than or equal to 5 °C of the average of four summer months (June, July, August and September) over sixty years.

Threshold ≥ MinT average + 5 °C

Threshold ≥ MaxT average + 5 °C

MinT and MaxT of daily temperatures exceed thresholds (both at once) are considered as a day of intense heat.

In our study, a heat wave is any period of more than two consecutive hot days.days.

3. Results and Discussion

3.1. Thermal amplitude in Algeria

We have processed the temperature data (MaxT and MinT) by region: the coastline, the highlands, the northern Sahara, the central Sahara and the extreme south of Algeria.

3.1.1. The results of Mann-Kendall trend test

The analysis of temperatures (maximum and minimum) for the period 1951-2010, demonstrates that the number of warm days and heat waves have risen during the last thirty years. This upward trend began in the 1990s (Faci, 2016 b).

The findings of Mann-Kendall test on the means of the so-called hot period (June to September) are not meaningful on all resorts with regard to the minimum temperatures; this is also the case for the maximum temperatures, except at the Tamanrasset station, which has a tendency to increase significantly at the 5% level.

The upward trend in maximum temperatures at Tamanrasset region began around 2005 (Figure 3).

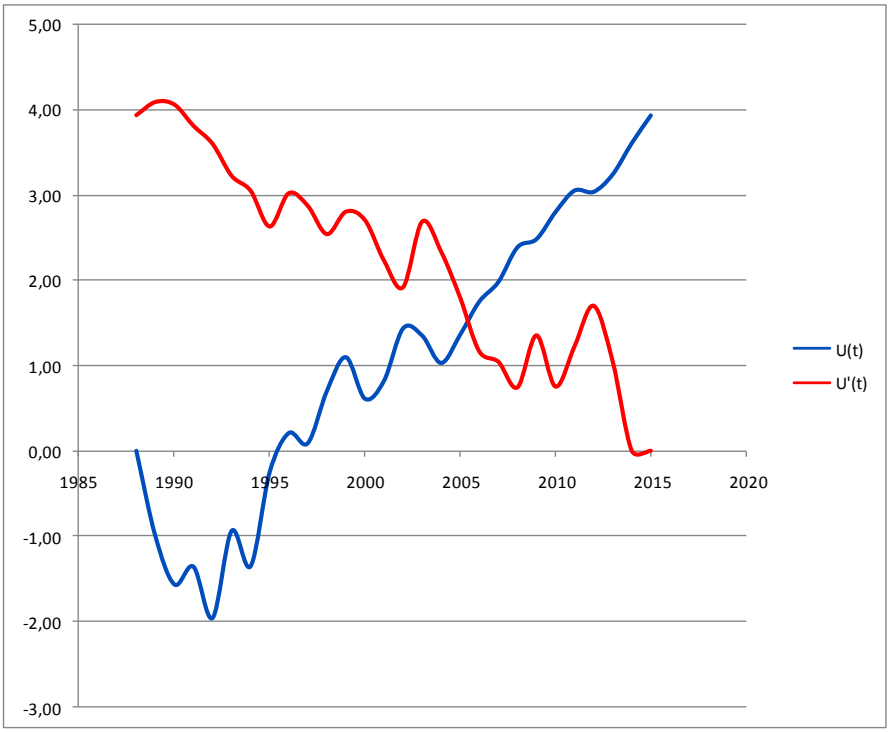

Figure 3. Mann-Kendall trend test for maximum temperatures in Tamanrasset station.

3.1.2. Thermal amplitude in the littoral

For the three coastal stations (Algiers, Annaba and Oran), the average of temperature during four months shows that the thermal amplitude varied between 9.5 °C and 13.5 °C (Figure 4).

In Algiers, the amplitude is higher compared to the other two large towns on the coast. This is probably due to the fact that the capital has more developed urbanization.

From 2008, the variability is lower in the three stations.

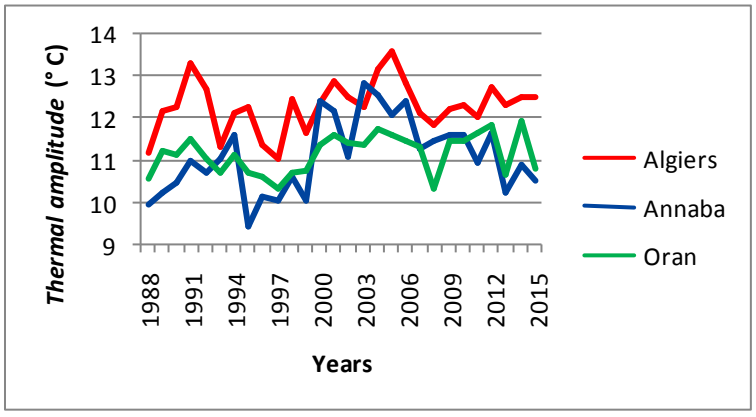

Figure 4. Variation in thermal amplitude at the coast.

3.1.3. Thermal amplitude in the highlands

As regards the five (05) highland stations are listed from 4 to 8 (see Table 1), the thermal amplitude varied between 13 °C to 18 °C and it is especially the eastern stations (Batna, Tébessa and Djelfa) which have the highest amplitudes. For the latter, the difference between MaxT and MinT has expanded in the early 2000s (Figure 5).

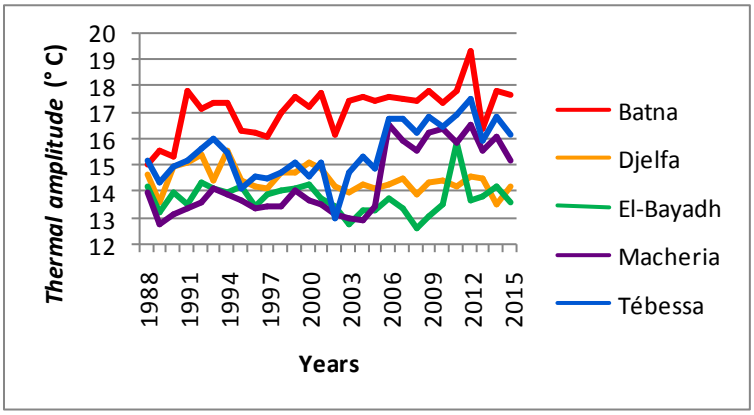

Figure 5. Variation of thermal amplitude in the highlands.

3.1.4. Thermal amplitude in the northern Sahara

The thermal amplitude in the northern Sahara stations varies between 11.9 °C and 15 °C.

At El-Oued station in the north-eastern Sahara, the variation (MaxT - MinT) is higher compared to the other two stations, namely Béchar in the west and Ghardaia in the center (Figure 6).

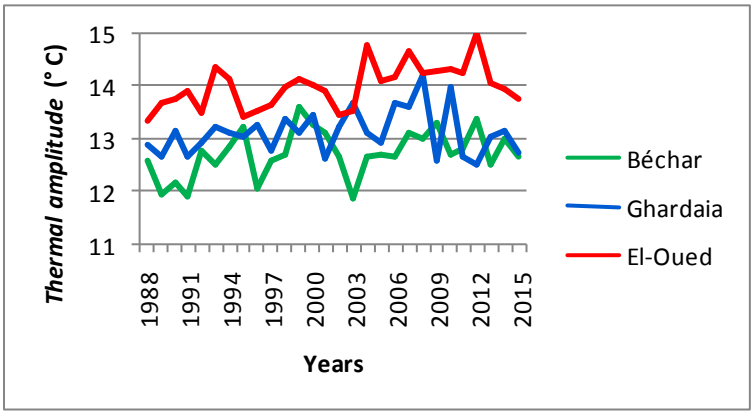

Figure 6. Variation of thermal amplitude in the northern Sahara.

3.1.5. Thermal amplitude in the central Sahara

The average thermal amplitude (average during four months) varies between 14.5 °C and 18.2 °C. We noticed that the highest temperature is at Tindouf station, practically for all years, and there is more similarity between In Aminas and In Salah (Figure 7).

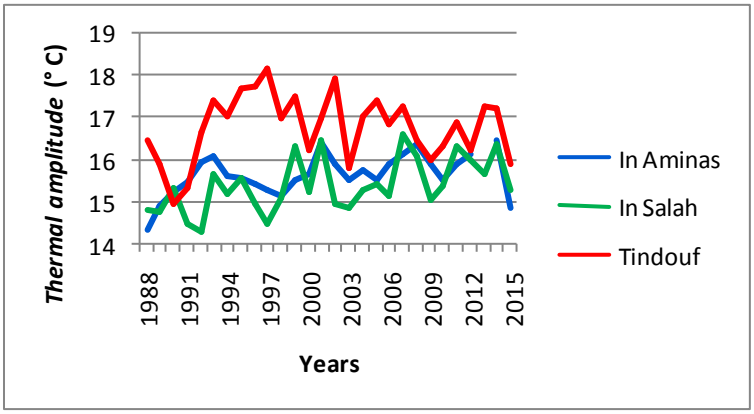

Figure 7. Variation of thermal amplitude in the central Sahara.

3.1.6. Thermal amplitude in the extreme south

The difference between MaxT and MinT throughout the warm season is much higher in the In Guezzam station where it varies between 13 °C and

16.7 °C. While in Tamanrasset it is between 11 °C and 14 °C (Figure 8). This is probably due to the effect of altitude; the Tamanrasset resort is more than 1360 meters above sea level, while the In Guezzam resort is at an altitude of 401 meters.

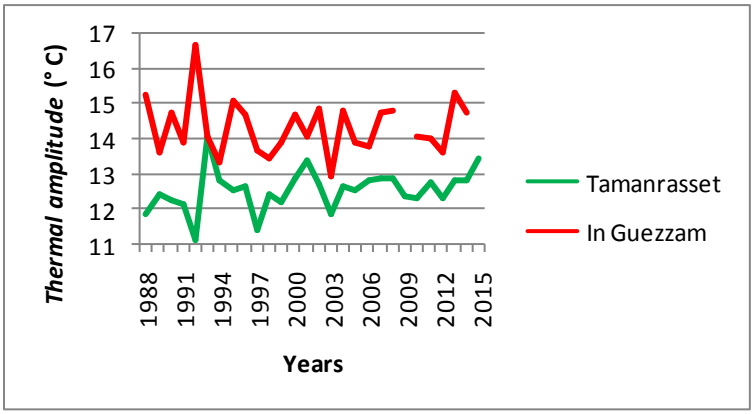

Figure 8. Variation of the thermal amplitude in the extreme south.

3.2. Heat waves in the Algerian Sahara

3.2.1. Determination of thresholds

The data processing has allowed us to determine the thresholds for each bioclimatic zone of the study area. The thresholds are taken into account in Table 2:

Table 2. Determination of thresholds.

Bioclimatic zone	MinT (°C)	MaxT (°C)
North Sahara	27,5	42,5
Central Sahara	30	47,5

3.2.2. Evolution of the number of hot days

The number of hot days, where MinT and MaxT are considered superior to the threshold, experienced an increase of more than 100% during the period 1981-2010 compared to 1951-1980. This increase is most notable from the mid-1990s in all stations (Figure 9).

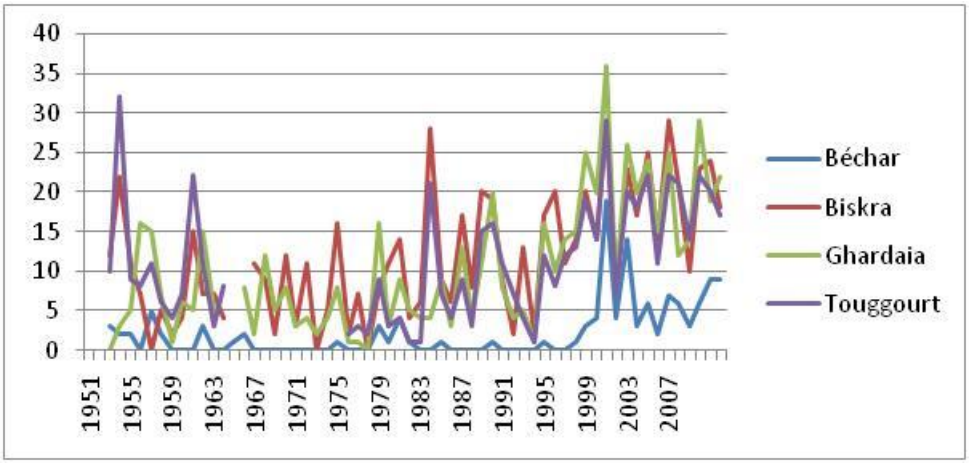

Figure 9. Evolution of the number of hot days in the North Sahara (Days).

3.2.3. Evolution of the number of heat waves

The number of heat waves saw a rising trend in the second half of analysis series. Also, the highest rate varies from one station to another, rising from 100% at Timimoune's station, where we recorded a modest increase up to 400% at Béchar's station (Table 3). The upward trend has accelerated from the middle of ninety years.

Table 3. Number of heat waves.

Stations	1951-1980	1981-2010
Béchar	3	15
Biskra	23	67
Ghardaïa	24	59
In Salah	7	21
Timimoune	4	8
Touggourt	14	52

We should point out that Ghardaïa and Biskra weather stations have recorded a high rate of heat waves compared to other stations, rising from an average of 0.76 heat wave / year to an average of 2.23 heat wave / year in Biskra.

The situation remains particular at Timimoune, with a very limited number of heat waves (12 cases in total) compared to other stations.

3.2.4. Period of heat waves

The monitoring of the first day of extreme heat period is carried out in all weather stations and compared to the first years of the series. Also, this precocity is observed about a week in North Sahara and two weeks in the Central Sahara stations.

At the end of intense heat wave period, the last record of more than two consecutive days of extreme heat, we observed a lateness of around three weeks on the North Sahara. For cons, the situation has remained more or less stable in the central Sahara.

The first and last records confirmed that heat Waves are becoming more frequent and longer in duration (Figure 10).

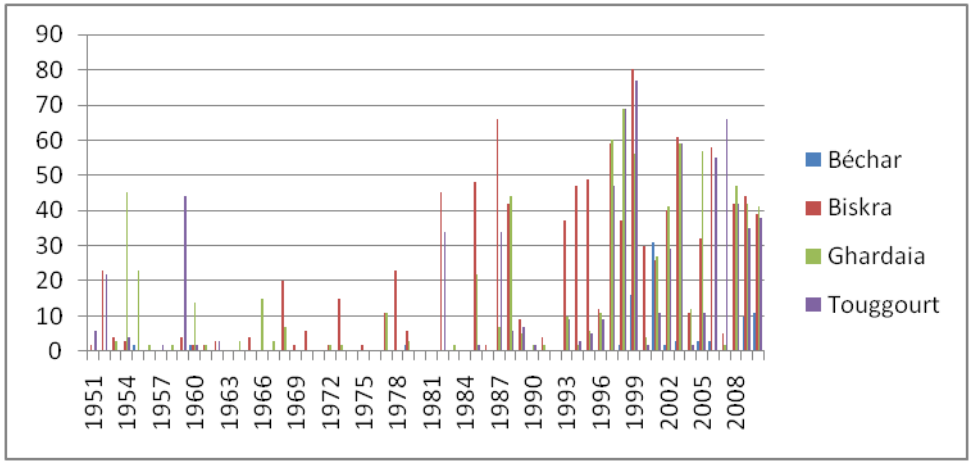

Figure 10. Duration of the heat waves period in the North Sahara (Days).

4. Conclusions

The averages of the maximum and minimum temperatures of the warm season, in Algeria, did not show a significant upward trend during the 28 years of the analysed series. However, Tamanrasset station is the only one (among the 16 stations) where we have recorded an a substantial increase in Tmax.

Starting in the 2000s, the difference (MaxT - MinT) has been rising. This increase is more remarkable in the highland resorts.

The highest intervals are identified at Algiers in the coastline, Batna in highlands and Tindouf and Adrar in the Sahara.

In the highlands and northern Sahara, the highest variations are recorded in the east of the country.

In the Sahara, the lowest thermal amplitudes are recorded in Tamanrasset.

The comparison between the two periods 1951-1980 and 1981-2010, shows a clear upward trend in the number of hot days and the number of heat waves, this increase has accelerated from mid-1990 in all stations.

The duration of the registration period of heat waves has lengthened about four weeks in the North Sahara and about two weeks in Central Sahara. Heat waves have become increasingly longer and more frequent during the last thirty years, in line with global warming.

Generally we can say that the tendency to overheating is clearly visible in the Algerian Sahara, which is usually known as a warm region.

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