



# Climate change impact on rainfall spatio-temporal variability (Macta watershed case, Algeria)

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**Abstract** This work describes the climate change impact study on rainfall patterns in Macta watershed, located in the northwest of Algeria. The monthly rainfall data collection, verification and validation have built a database with 42 stations, each with 42 years of observations from 1970 to 2011. The study of annual total rainfall has identified a downward trend and quantifies the deficits that are within the observation time series. The division of the annual rainfall series into four periods allowed to highlighting the increase in inter-year temporal variability with the coefficient of variation increases from 17 to 27%. The study shows an annual rainfall deficit increment from 13 to 25%. The standard deviation values decrease significantly for the last two periods showing a spatial variability. Multivariate statistical study by the hierarchical clustering method resulted in the formation of station groups indicating the unification of monthly rainfall patterns.

**Keywords** Climate change · Water resources · Spatial variability · Drought · Macta watershed · Algeria

## Introduction

The Earth's climate is naturally subject to variations. The land has regularly experienced periods of warming and cooling periods, which are still parts of natural climate cycles. However, human activity has exacerbated the problems associated with climate change. Anthropogenic climate change is predicted to cause spatial and temporal shifts in precipitation patterns (Marvel et al. 2017). The time series study, to highlight the climate change effect on the meteorological data variability, has been the subject of several researches (Kundzewicz et al. 2005; Donat et al. 2014; Raziei et al. 2014, Elmeddahi et al. 2016). Ogburn (2013) reported that global precipitation shifts across land and ocean. The various parts of the world or even parts of some countries react differently to the global warming effects. Thus, the types of impacts of climate change are different between the semi-arid, arid and wet areas in the world (Şen et al. 2012). According to the report and the projections of the Intergovernmental Panel on Climate Change (IPCC 2007), the annual average rainfall is expected to decline in the Mediterranean and the Arabian Peninsula between 10–20% and 30–40% in Morocco and northern Mauritania, respectively. While 10 to 30% increase in precipitation is expected in the Kingdom of Saudi Arabia, Yemen, the United Arab Emirates and Oman (Jnad and Siba 2006).

The climate change effects in the Maghreb countries might be more pronounced than elsewhere because of the Sahara vicinity having hyper-arid climate. Now, the climate change ahead is a major concern for Maghreb states (Taabni and El Jihad 2012). Turki et al. (2016) have noted significant changes of rainfall variability in Northeastern Algeria.

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For these reasons, it is a prerequisite for water resources planning to know the direction of change whether in an increasing or decreasing manner so as to support regional water and food exchange possibilities for the sustainability of a society.

The main impact on Algeria is desertification, which involves usually a decrease in the amount of some meteorological and agricultural items such as rainfall, vegetation cover, the extension of water surfaces, groundwater levels and crop yields (Şen 2008). In this regard, it is important to emphasize that a healthy water resource management in Algeria is unthinkable without considering the climate and its variations.

This study focuses on the watershed Macta and aims to know the changing rainfall patterns. The first objective is to collect, verify and validate the monthly rainfall data forming the longest possible series. The second stage is to study the trends of annual and monthly rainfall series and finally the formation of stations groups with the same rainfall pattern for different periods and for possible climate change determinations. This work is based on the data analysis methodology, which aims to reason about any number of variables not only in pairs (De Lagarde 1983).

## Methodology

### Study area

The Macta watershed is located in the northwest of Algeria with an area of 14,389 km<sup>2</sup>. It is bounded to the northwest by the mountain ranges of Tessala, in the south by the highlands of Maalif, in the west by the Telagh plateau and in the east by the Saldas' mountains (Meddi et al. 2010).

The Macta watershed is the most important western Algerian Basin that drains the main water resources to the west (Fig. 1).

Due to its elongated shape, the basin is characterized by a strong surface flow in the upstream part of the river, and it is drained by two major rivers, Mékerra and Wadi El-Hammam, which join not far from the Mediterranean coast to form Macta. Annual rainfall decreases from north to south and varies on the average from 500 down to 300 mm. On the mountains of Saida, in Aouf, it can reach to 600 or 700 mm per annum. Regarding the monthly average, usually January is the wettest, and July is the driest month.

### Data collection and processing

#### *Stations and the study period selection*

Data are obtained mainly from the National Office of Meteorology (ONM) and the National Agency for Water Resources (ANRH).

For an effective data processing, it is necessary to have sufficiently long periods of records. This is essential not only to know the traits of a climate but also to monitor its evolution. However, the reality is different, because often there are gaps in the observation series.

The present study is based on monthly rainfall records without significant gaps unlike temperature, wind, humidity, etc., where important discontinuities are observed within the record series.

To ensure a good representation of the region, data are collected from 123 rainfall stations with periods as long as possible. Years and stations with more than 10% gaps were removed (Meddi et al. 2014). Finally, 42 stations are selected from 1970 to 2011, inclusive. Figure 2 clearly illustrates years with percentage gaps.

The spatial distribution of the station locations is presented in Fig. 3 with distinctions among the coastal, mountains, hills and plains stations (Fig. 3).

## Statistical analysis

### *Outliers*

An excellent analysis on false data obviously has no value. Any analysis involves two steps, namely, data collection and processing. It is clear that the first operation is very important for obtaining reliable results from the second step. Whatever the initial data, one can often find anomalies in rainfall series. It is almost always necessary to make a critical study prior to direct use of available data (Laborde 2013). Data verification can highlight certain values that can appear as singulars compared to the rest of the series. The singularity can express a transcription error (outlier) during the various manipulations of the data or simply rare local weather phenomena (exceptional data). An outlier can be considered an observation, which abnormally or haphazardly deviates from normal status of data and analysis (Noughabi 2011).

Groups of neighboring stations are formed for each month by considering matrices, which are classified into monthly value columns. Each pair of these matrices is subjected to the outlier detection procedure with Hydrolab Excel Macro software (Hydrolab 2010), which uses the accumulated residual method.

The basic idea is to study the cumulative residue  $\varepsilon_i$  between the values and the estimated values by the regression line (Yue Rong 2011). These totals are calculated by the following formula (Yue Rong 2011):

$$Z_i = \sum_{j=1}^i \varepsilon_i \quad (1)$$

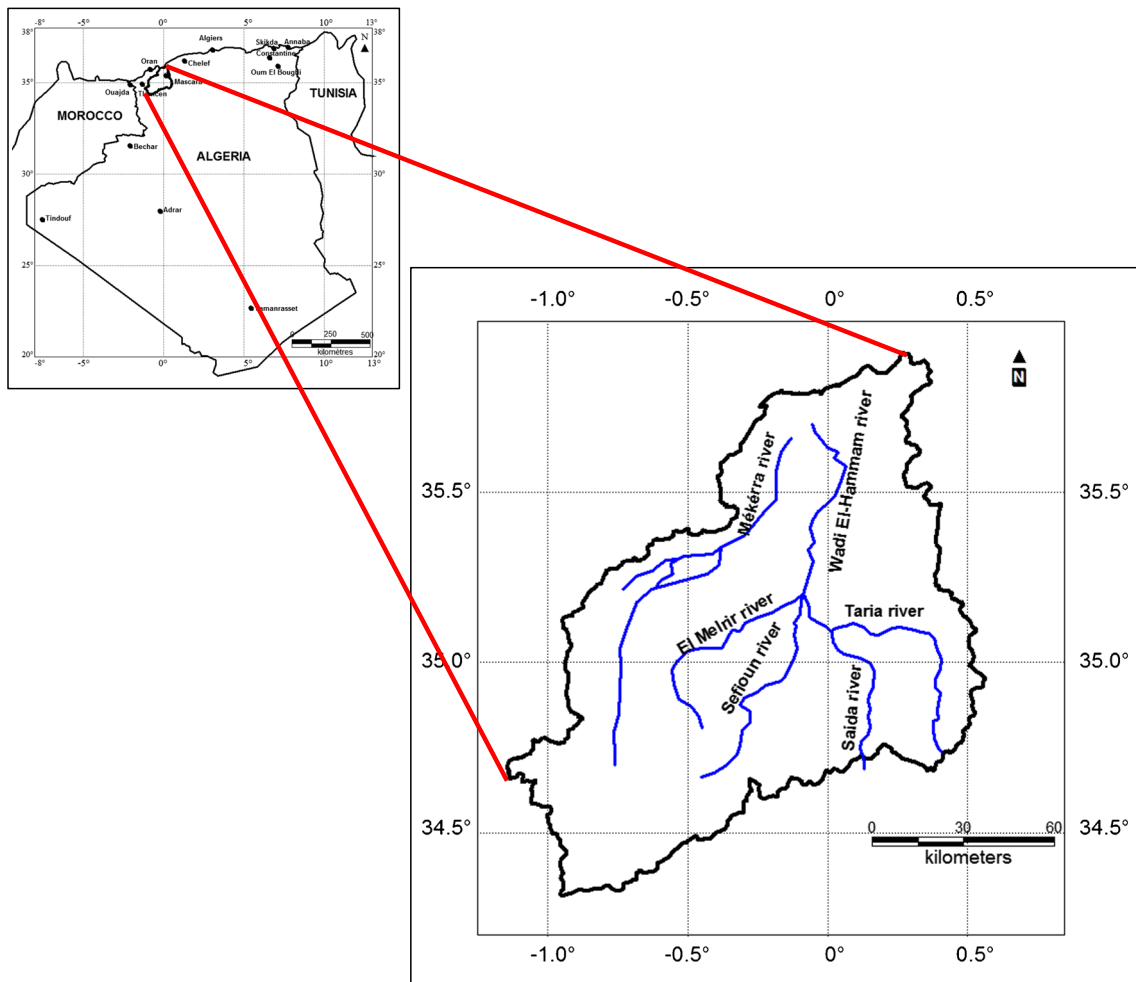


Fig. 1 Macta watershed location

where  $Z_i$ s are random variable with mean zero and standard deviation  $\sigma_{z_i}$ . One can build for each  $Z_i$  value, a confidence interval (for a given significance level) according to the following expression:

$$\left[ -u_{1-\frac{\alpha}{2}}\sigma_{Z_i}, u_{1-\frac{\alpha}{2}}\sigma_{Z_i} \right] \tag{2}$$

where  $u_{1-\frac{\alpha}{2}}$  is a reduced Gauss variable for a two-tailed test and  $\sigma_{Z_i}$  is calculated as,

$$\sigma_{Z_i} = \sigma_\varepsilon \sqrt{\frac{i(n-i)}{n-1}} \tag{3}$$

where  $n$  is the number of observations and  $\sigma_\varepsilon$  is expressed according to the following expression:

$$\sigma_\varepsilon = \sigma_y \sqrt{1-r^2} \tag{4}$$

where  $\sigma_y$  is the tested variable standard deviation and  $r$  is the correlation coefficient.

On a graph (Fig. 4), one can indicate on y-axis residuals ( $Z_i$ ) with the upper and lower bounds of the confidence intervals, which form an ellipse. The cumulative gap out of the

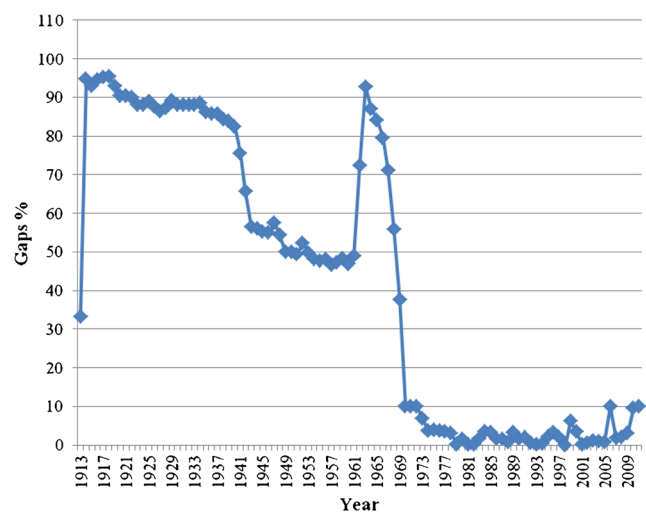
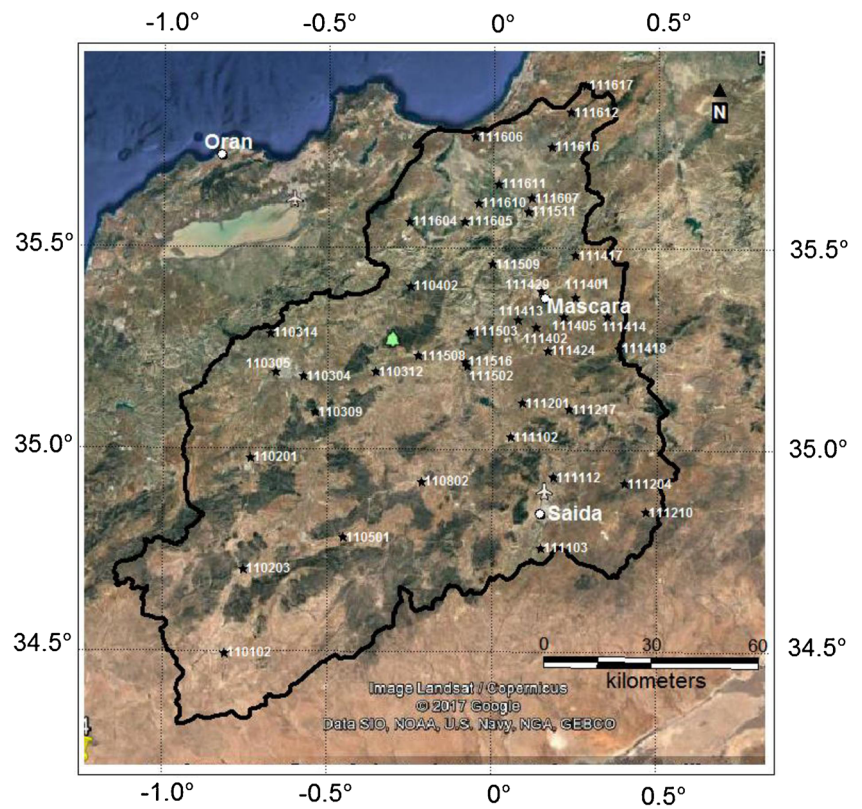


Fig. 2 Year percentage gaps

Fig. 3 Selected weather stations



ellipse is considered an outlier. Subsequently, one can have the chance to compare it with other matrix columns either to dismiss or to validate (exceptional value).

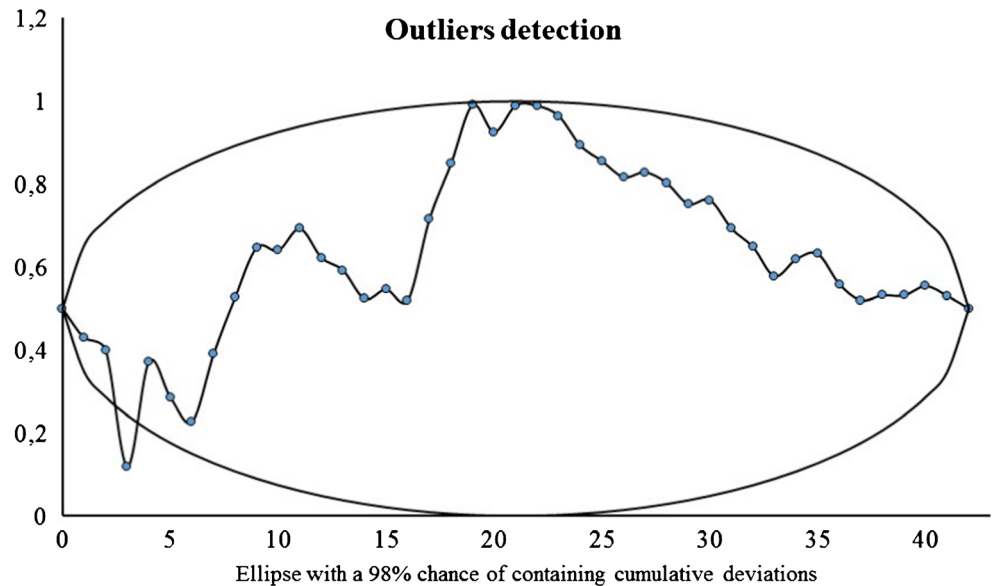
*Filling gaps*

Environmental time series are often affected by the “presence” of missing data, but when dealing statistically with

data, the need to fill in the gaps estimating the missing values must be considered (Lo Presti et al. 2010). After inserting these estimates, data analyses can continue almost as if no value is missed.

On an Excel spreadsheet, the missing data are replaced by “lac”. They are then estimated by using the Hydrolab software (Hydrolab 2010). This software uses the principal component analysis (PCA) to estimate missing data. According to

Fig. 4 Outlier detection example



Laborde (2013), seven to eight iterations are sufficient to stabilize the process. At this stage, the data are complete and ready for the analysis.

#### *Data analysis (or exploratory multivariate techniques)*

Multivariate exploratory data analysis methods also known as principal component methods are dimensionality reduction techniques often used to sum-up data, where individuals are described by continuous and or categorical variables (Josse and Husson 2012).

Data analysis mainly covers two sets of techniques: the first is Factor analysis, where variables that are correlated with each other are combined (Gordon et al. 2004); the second technique is the “automatic classification”, which is for partition of the data into groups, where objects that are similar tend to fall into the same groups and objects that are relatively distinct tend to separate into different groups (Yang 2012). These two techniques are used either alone or jointly.

The principal components factor analysis was developed by H. Hotelling (1933), but it can be traced back also to Pearson (1901) (Ambapour 2003). It is a multi-dimensional statistical approach that allows for a comprehensive study of involved data. It also helps to summarize, represent, organize, visualize and define the relationships that may exist among the variables. The classification methods such as hierarchical clustering (hierarchical cluster analysis or HCA) is the best known and most experienced technique. It is most useful to discover groups and interesting pattern identifications (Halkidi et al. 2001). It is also known as an effective statistical tool to group stations in homogeneous climatic regions (De Gaetano and Shulman 1990; Ahmed 1997; De Gaetano 2001). After calculating distances between individuals in pairs, one must choose a criterion to discriminate among the trees with different topologies (Pardi and Gascuel 2012).

## Results and discussion

### Graphic study

The graph of annual rainfall in Fig. 5 imposes the following comments:

- Macta Watershed annual rainfall varies between 71.5 and 1033.1 mm and indicates a high spatial and temporal variability.
- Years 1996 and 1997 represent a phenomenon that has caught the attention. Most stations had an exceptional year (1996) and a drought year (1997).
- This last remark helped to note that from these two years, the majority of lines converge. This gave the idea to test the rainfall patterns unification hypothesis on the monthly scale.

Figure 6 represents the annual rainfall sum of the 42 stations. It shows a clear downward trend with  $-31.228$  slope. The year 2009 represents the maximum records with a total rainfall of 21,165.7 mm, while 1982 has the smallest total with 7751.6 mm. The recent years indicate droughts that are longer in time durations but closer to each other in space (Stockton 1988; Mutin 2011).

The seasonal rainfall is represented in Fig. 7. The winter, the wet season, is most affected by the rainfall decline. It has the biggest trend slope ( $-38.417$ ). On the other hand, summer is characterized by an increasing trend, influenced by exceptional rains that occur in a random manner. The latter affects the stations variability.

To quantify the rainfall reduction in time, the study period is divided into four periods. For each year, the rainfall totals are calculated with each sub-period average (Table 1) in addition to the percentage reduction relative to the first sub-period (1970–1979). The averages range between 15,384 and 11,466.5 mm. The two sub-periods, 1980–1989 and 1990–1999, have the minimum average within the study period with a percentage reduction of about 25%. The period of 2000–2011 has an increase compared to the previous periods, but it has a decrease of 13.2% compared with the first period. Meddi et al. (2010) observed also a decrease of at least 20% of total annual rainfall at five stations in Macta and Tafna catchments. This can directly affect the agriculture. Also, several studies indicated that many cultures will increase, in future, their demand on water due to the global warming (IPCC 2008; Brauch 2007; Maracchi et al. 2005; Agoumi 2003; Fischer et al. 2005).

The coefficients of variation fluctuate between 17 and 28%, indicating increased temporal variability of annual totals.

Regarding the spatial variability of monthly rainfall patterns, one can calculate the standard deviation of each station for each sub-period. The graphical representation and interpretations are as follows (Fig. 8):

- The standard deviation values have a greater variability for the first and second sub-periods, while they decrease significantly for the last two sub-periods.
- The stations' standard deviations are close while in decrease. Thus, seven (6.66%) stations only have one standard deviation below 30 for the first time period against 28 (66.66%) for the last period.

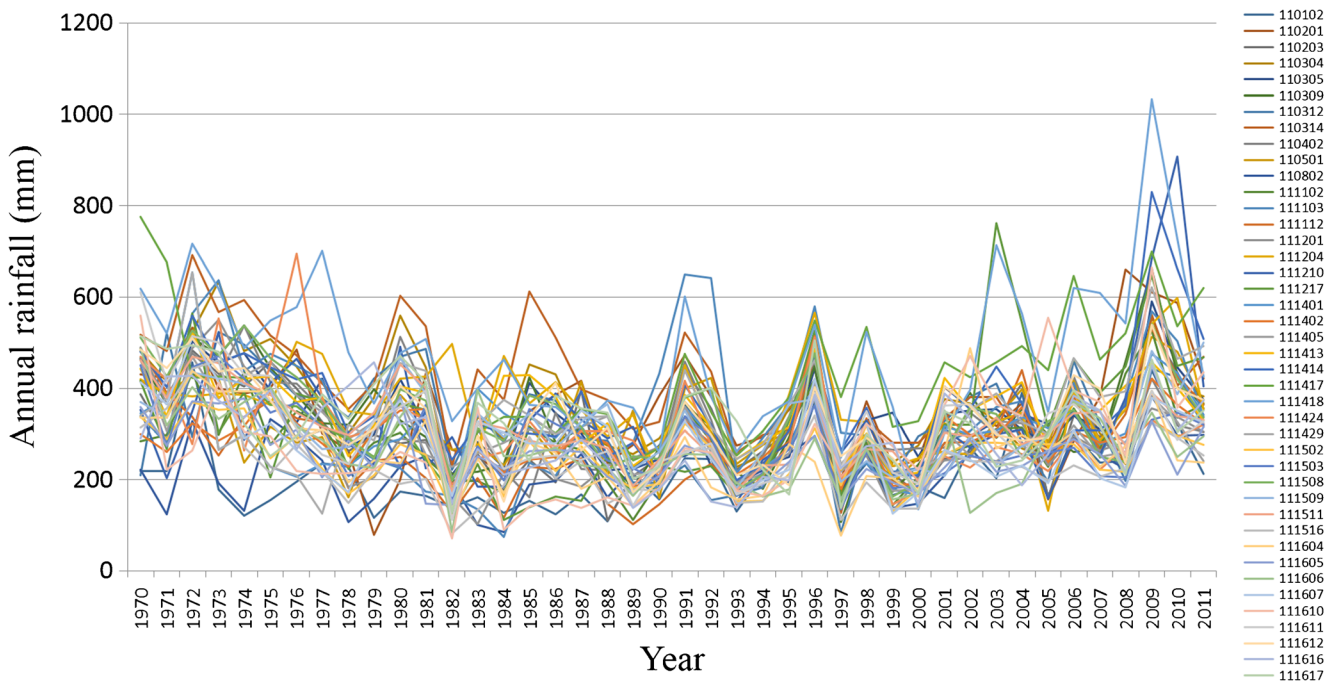


Fig. 5 Annual rainfall of the Macta watershed 42 stations (1970–2011 period)

Regarding the seasonal variability, the majority of stations indicate a decrease. This decrease is accompanied by a reconciliation of the standard deviation values. With the exception of the summer season, where there is an increase in variability, others are influenced by extreme rains (Fig. 9).

**Formation of homogenous groups**

The data processing affecting the automatic classification is done by using the STATISTICA software (StatSoft France 2003).

The purpose is the formation of groups that have the same rainfall pattern (monthly rainfall) and not the same annual

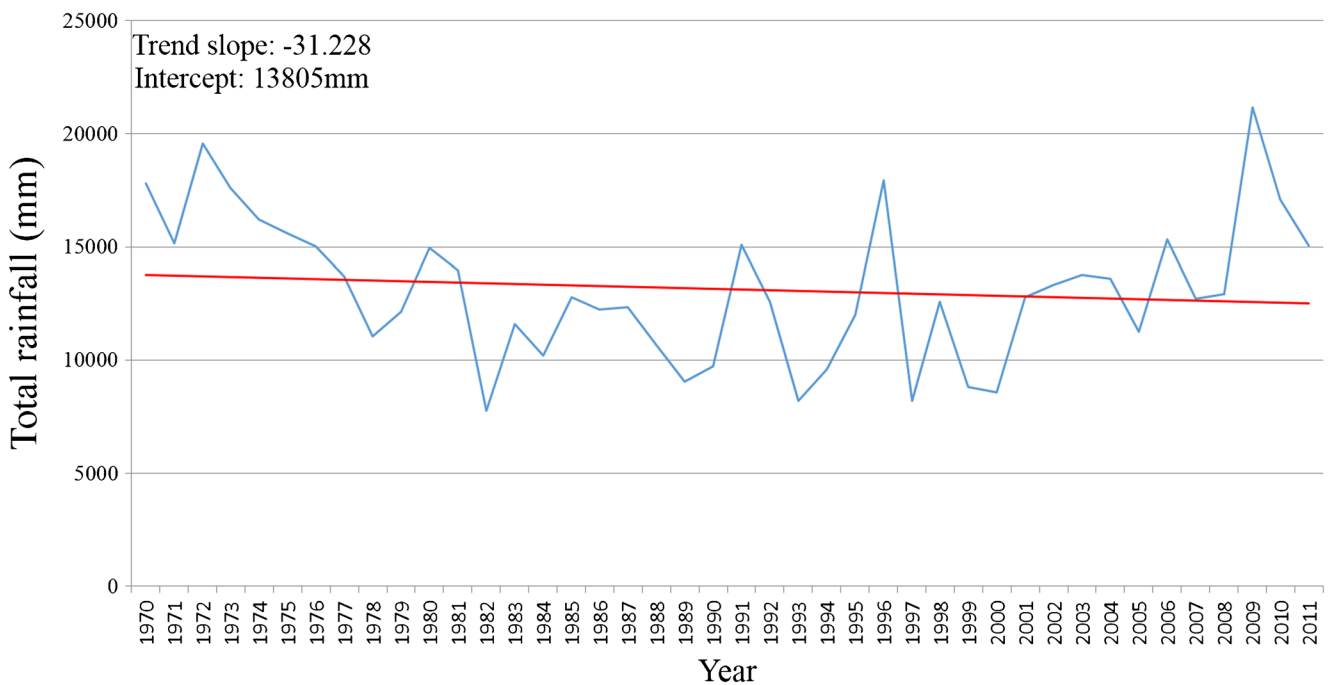


Fig. 6 The 42 stations' rainfall amount

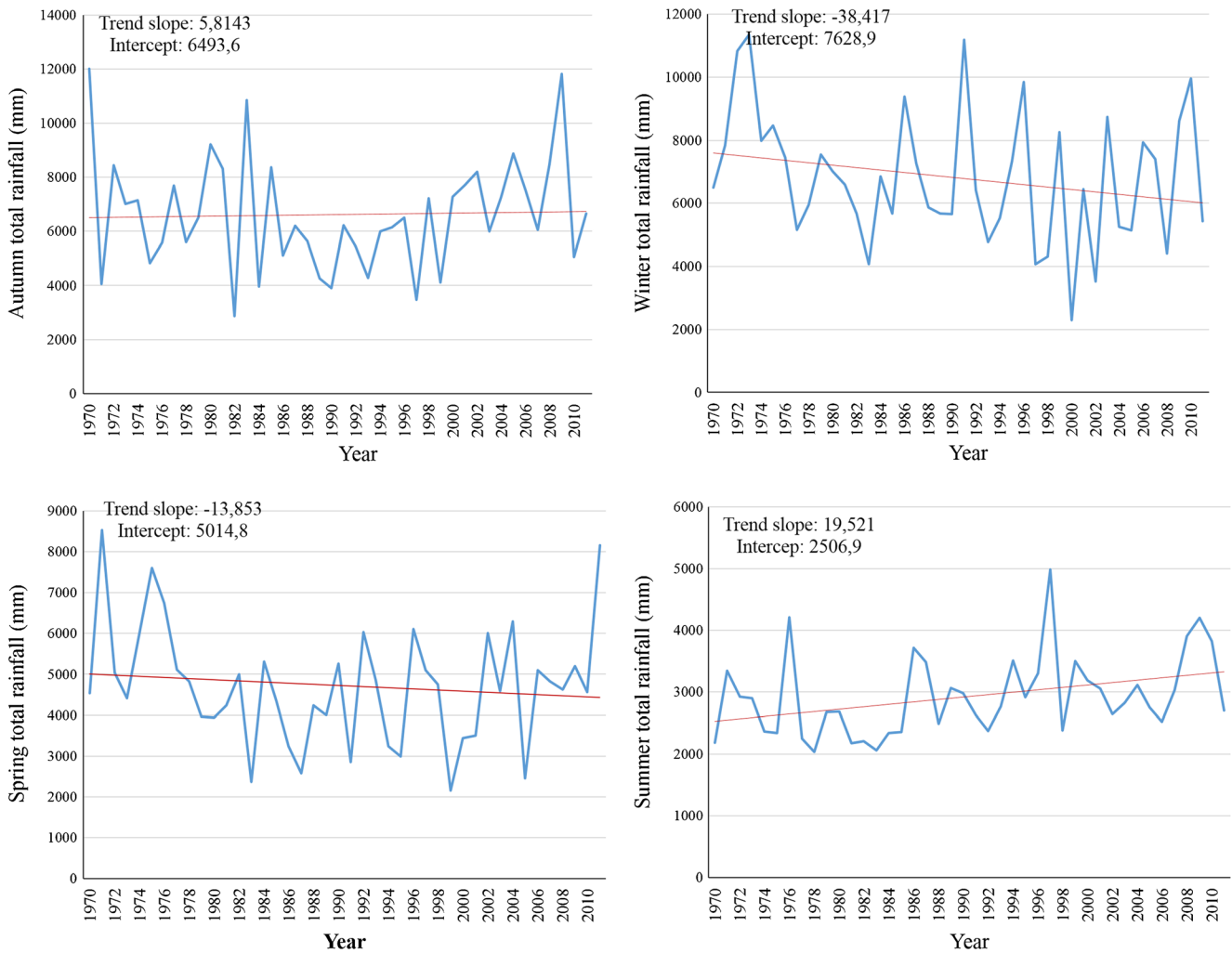


Fig. 7 The 42 stations’ seasonal rainfall amount

rainfall. Two stations may have the same annual rainfall, but they may not be part of the same group, if the distribution of monthly precipitation is not similar.

To confirm the above interpretations by graphical study and to show clearly the influence of climate change on rainfall patterns, one can form a matrix for each sub-period with 42 columns. The processing of monthly rainfall by hierarchical clustering of the four sub-periods led to four graphics called dendrograms (Figs. 10, 11, 12, 13). Their use facilitates group formations and subsequent interpretations.

Figures 10, 11, 12 and 13 show on abscissa the codes of the stations and on the ordinate the aggregation distances between the different stations.

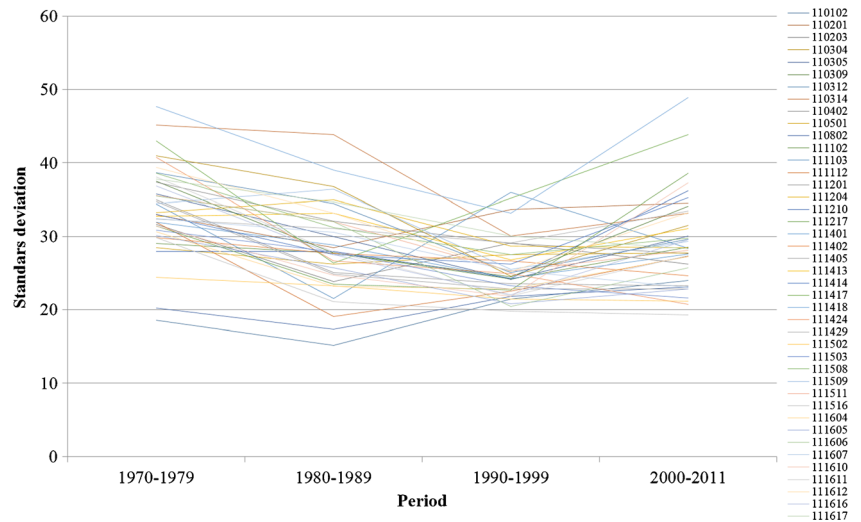
Among the methods used by the hierarchical clustering, one can find the notion based on the minimum jump criterion. This involves choosing the smallest of distances, which allow moving from one class to another (Ambapour 2003). This distance is considered critical.

Dendrograms in Figs. 10, 11, 12 and 13 are used for the groups’ formation. The Euclidean distance is used as a criterion of similarity (critical distance). One can draw a horizontal

Table 1 Total annual rainfall average

Period	Average (mm)	Percentage reduction (%)	Standard deviation	Coefficient of variation (%)
1970–1979	15,384.0		2616.13	17.00
1980–1989	11,555.3	24.89	2190.11	18.95
1990–1999	11,466.5	25.46	3214.00	28.03
2000–2011	13,352.5	13.20	3697.74	27.69

**Fig. 8** Monthly rainfall standard deviation for different stations (for each sub-period)



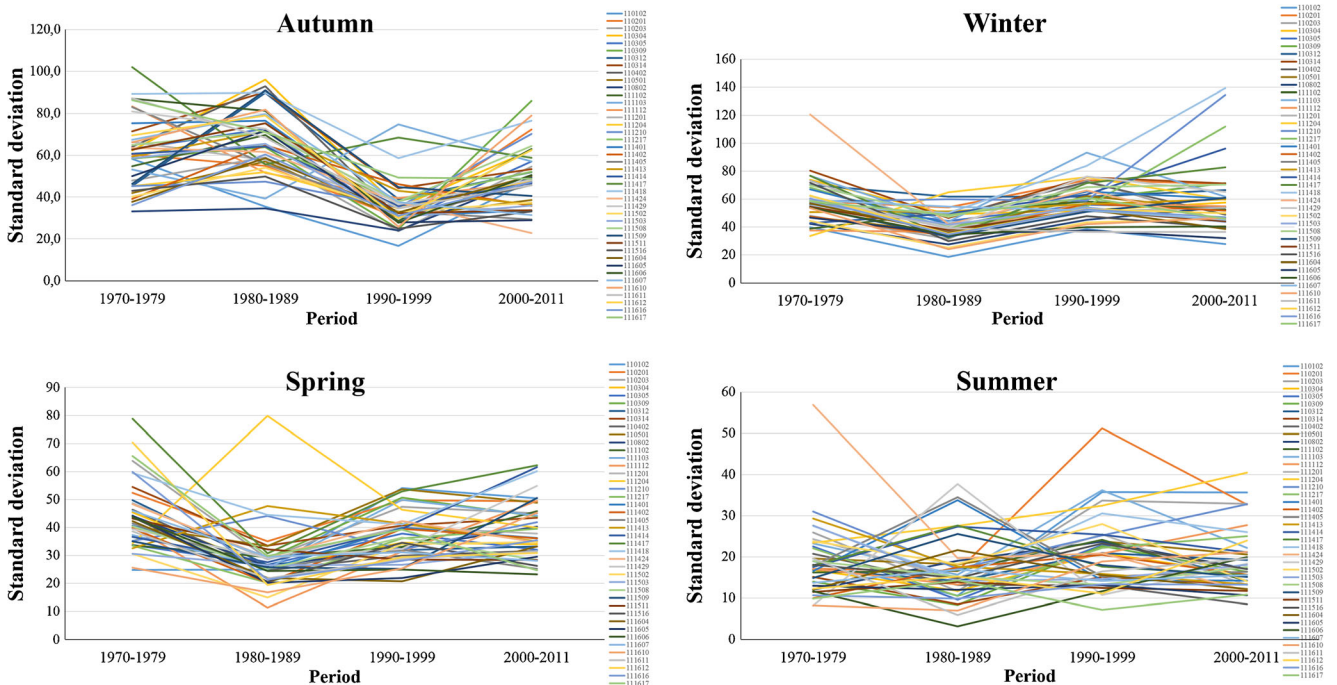
line (critical aggregation distance) through the diagram at any level on the y-axis (the distance measure); the vertical cluster lines that intersect the horizontal line indicate clusters, whose members are at least that close to each other. A critical aggregation distance is set equal to 150 for the four sub-periods. If the distance between stations is greater than 150, they cannot belong to the same group.

The results are shown in the maps (Figs. 14, 15, 16, 17), where the stations within the same group are indicated by one color.

The analysis of Figs. 14, 15, 16 and 17 shows that station number per group tends to expand over time. Thus, the

maximum number of stations forming the same group (aggregation distances  $\leq 150$ ) for sub-periods 1970–1979, 1980–1989, 1990–1999 and 2000–2011 is 4, 4, 30 and 15 stations, respectively. These results lead to the conclusion that the monthly rainfall pattern of stations tends to unify. This unifying trend is accompanied by runoff declines reaching 20% (IPCC 2008; Mostefa-Kara 2008).

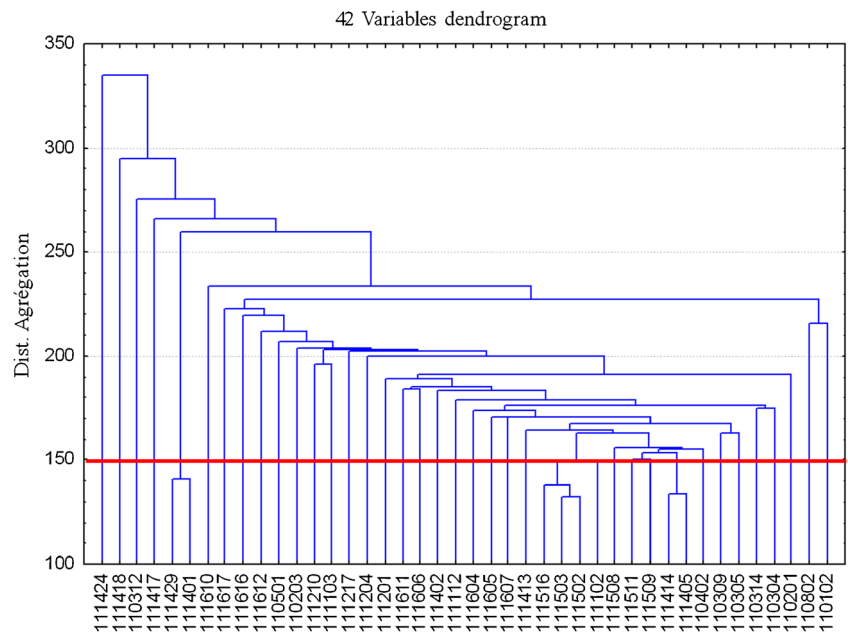
It is also possible to note that during the first two periods, the similarity of monthly rainfall patterns is related to the geographical position (two neighboring stations may belong to the same group). On the other side, the similarity in the last two periods is no longer linked to



**Fig. 9** Seasonal rainfall standard deviation for different stations (for each sub-period)



**Fig. 10** Dendrogram of period 1970–1979



neighborhood phenomenon but to rather a southern trend northward.

The same observation can be made using the stations' standard deviation interpolation by the kriging method. Figure 18 shows the iso-standard deviation lines. The latter have a west-east direction except the last period, where the direction is south-north.

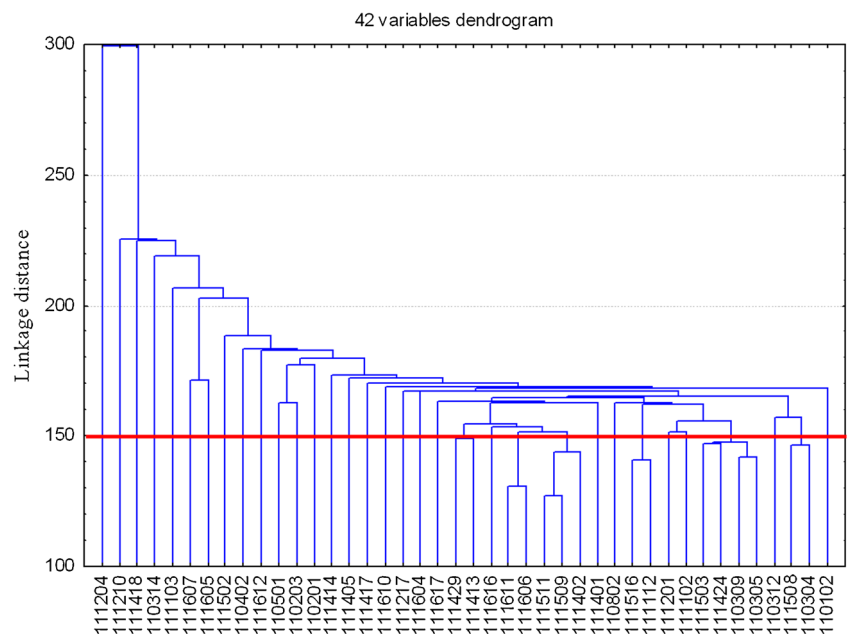
The same results are highlighted by Şen (2013) by showing that climate tends to shift from south to north. These changes have implications on hydrological extremes like droughts and

floods. They can also affect growing seasons and crop yields (Sultan et al. 2014).

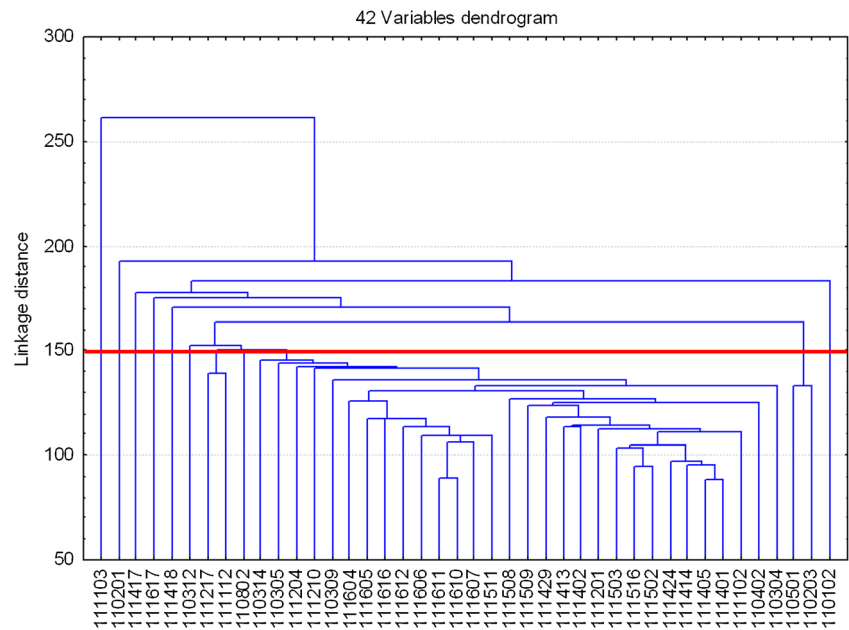
**Conclusion**

This study highlighted the climate change impact on the rainfall spatio-temporal variability. It could contribute to the scientific knowledge by providing factual information about the hydrology of the study region. The main results are the

**Fig. 11** Dendrogram of period 1980–1989



**Fig. 12** Dendrogram of period 1990–1999



decrease of the rainfall and variability. Data verification allowed to detect outliers and then to dismiss them. The gap-filling operation helped to build a database of 42 years' monthly rainfall records from 1970 to 2011 within the Macta watershed in the northwest Algeria.

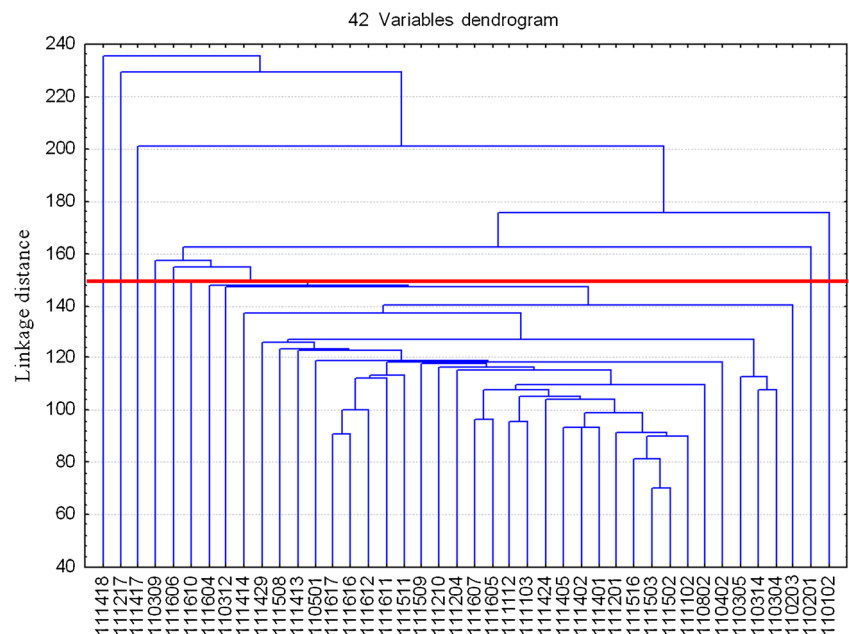
The total average annual rainfall tends to decline and pass from 15,384 to 13,352.5 mm, with a loss of about 13.2%. The dry periods are longer with few exceptional years.

The formation of four sub-period is used to determine possible rainfall evolution. Comparison of the coefficients of

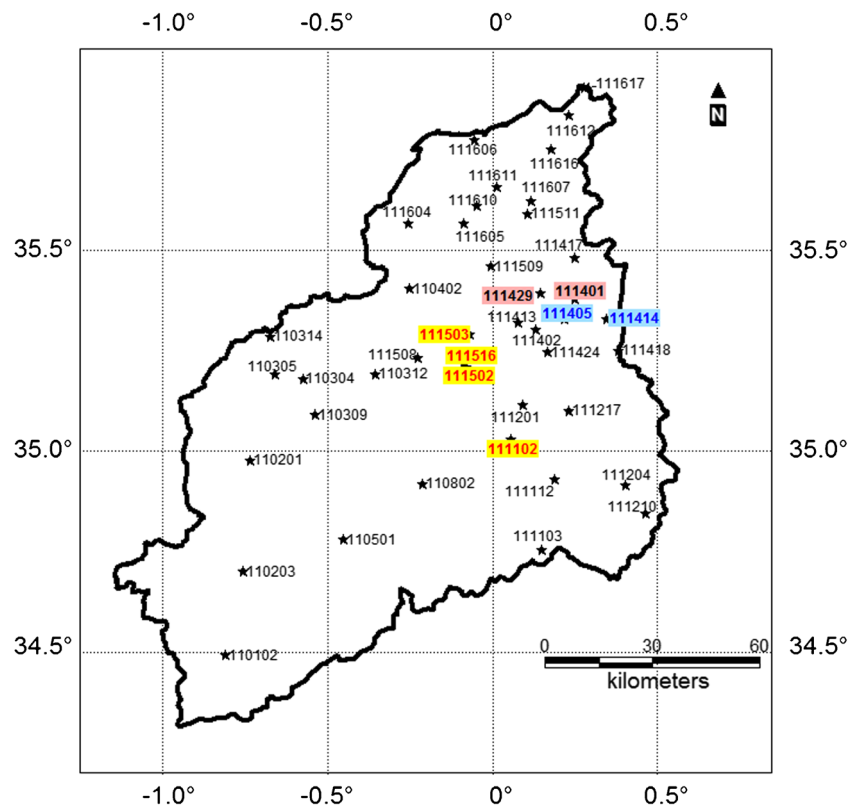
variations showed an increasing variability. The coefficient of variation is 17% during the period 1970–1979 but reached to 27.69% in 2000–2011, hence, indicating the decrease in the monthly rainfall variability. Only 17% of stations had a standard deviation less than 30, while more than 66% passes below this value during the period 2000–2011.

The hierarchical clustering methodology facilitates the stations' group formations based on similarity of monthly rainfall pattern. The maximum station numbers that can be in the same group for the periods 1970–1979, 1980–1989, 1990–1999 and 2000 are 4, 4, 30 and 15, respectively. This may imply a

**Fig. 13** Dendrogram of period 2000–2011



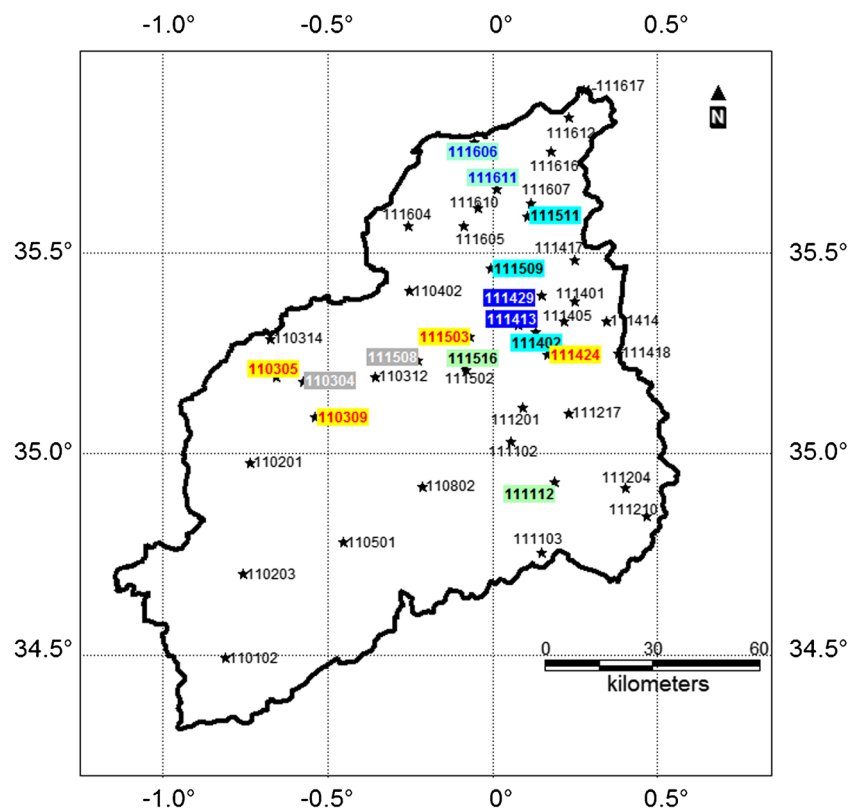
**Fig. 14** Stations' class with an aggregate distance  $\leq 150$  (period 1970–1979)



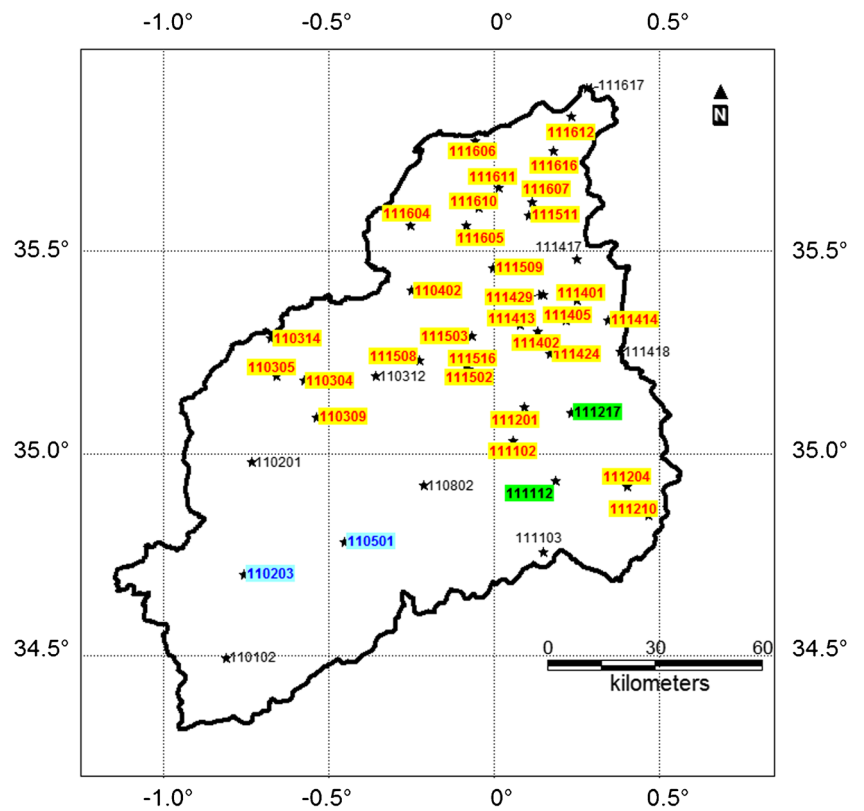
reduction in the spatial variability, and therefore, a unification of monthly rainfall patterns. Group representation on maps

shows that the unification phenomenon has a southern to northward trend.

**Fig. 15** Stations' class with an aggregate distance  $\leq 150$  (period 1980–1989)



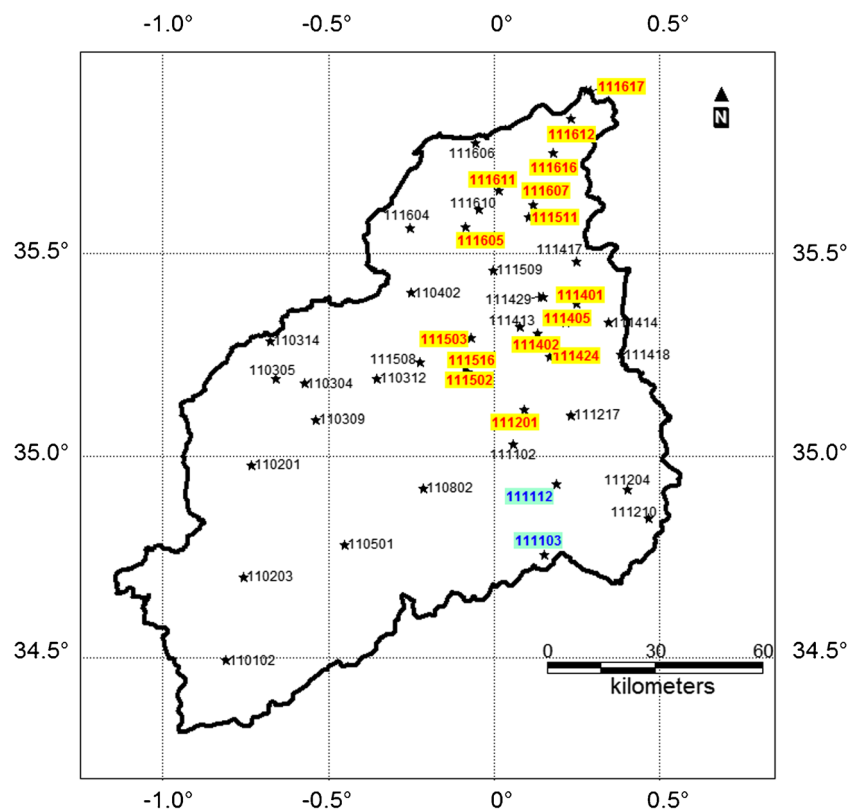
**Fig. 16** Stations' class with an aggregate distance  $\leq 150$  (period 1990–1999)

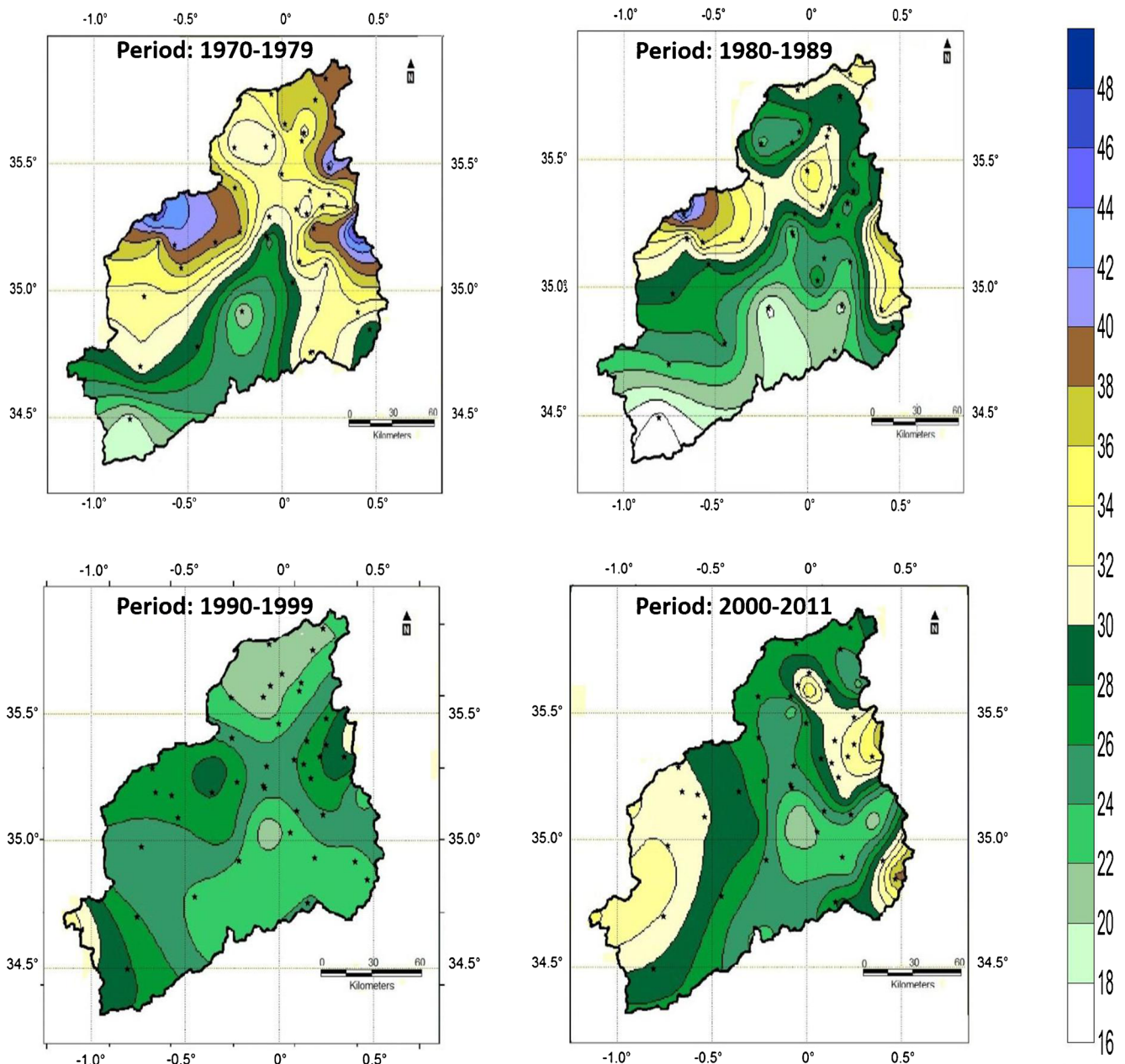


This evolution of the climate (temperature, precipitation, etc.) affects the global hydrological cycle, especially as it will

conjugate the watershed changes, especially due to activities (Jacques et al. 2006).

**Fig. 17** Stations' class with an aggregate distance  $\leq 150$  (period 2000–2011)





**Fig. 18** Standard deviation interpolation

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**References**

Agoumi A (2003). Vulnérabilité des pays du Maghreb face aux changements climatiques. International Institute for Sustainable Development (IISD), 11 p  
 Ahmed BYM (1997) Climatic classification of Saudi Arabia: an application of factor-cluster analysis. *Geo J* 41(1)  
 Ambapour S (2003). Introduction à l'analyse de données. Bureau d'application des méthodes statistiques et informatiques. Edition BAMSI reprint. 80p.

Brauch HG (2007). Impacts prévus des changements climatiques sur la vulnérabilité sécuritaire des centres urbains méditerranéens. Montpellier: Plan Bleu, Centre d'activités régionales, Environnement et Développement en Méditerranée, 41 p  
 De Gaetano AT (2001) Spatial grouping of United States climates stations using a hybrid clustering approach. *Int J Climatol* 21:791–807  
 De Gaetano AT, Shulman MD (1990) A climatic classification of plant hardiness in the United States and Canada. *Agric For Meteorol* 51: 333–351  
 De Lagarde J (1983). Initiation à l'analyse des données. Editions Dunod: Paris. - 157 p. ISBN 2-04-015493-0.  
 Donat MG et al. (2014). Changes in extreme temperature and precipitation in the Arab region: long-term trends and variability related to ENSO and NAO. Volume 34, Issue 3, pages 581–592. <https://doi.org/10.1002/joc.3707>

- Elmeddahi Y, Mahmoudi H, Issaadi A, Goosen MFA, Ragab R (2016) Evaluating the effects of climate change and variability on water resources: a case study of the Cheliff Basin in Algeria. *Am J Eng Appl Sci* 9(4):835–845. <https://doi.org/10.3844/ajeassp.2016.835.845>
- Fischer G, Shah M, Tubiello N et van Velthuizen H. (2005). Socio economic and climate change impacts on agriculture: an integrated assessment, 1990–2080. *Philosophical transactions of the Royal Society (series B: biological sciences)*, n° 360, p. 2067–2083.
- Gordon ND, McMahon TA, Finlayson BL, Gippel CJ, Nathan RJ (2004) *Stream hydrology, an introduction for ecologists*, Second edn. John Wiley & Sons, New Jersey, p 423
- Halkidi M, Batistakis Y, Vazirgiannis M (2001) On clustering validation techniques. *J Intell Inf Syst* 17(2/3):107–145
- HOTELLING HAROLD (1933). Analysis of a complex of statistical variables into principal components. *Journal of Educational Psychology*, volume 24, pages 417–441 and 498–520.
- Hydrolab (2010). Excel macro-commands developed by J. P. Laborde helped by N. Mouhous. Université de Nice-Sophia Antipolis et C.N.R.S.
- Intergovernmental Panel on Climate Change (IPCC), (2007). The fourth assessment report (AR4). <<http://www.ipcc.ch/>> (Mar. 14, 2008).
- IPCC (2008) Bilan 2007 des changements climatiques: synthèse du rapport d'évaluation du Groupe d'experts Intergouvernemental sur l'évolution du Climat (GIEC). Organisation Mondiale de Météorologie (OMM)/Programme des Nations Unies pour l'Environnement (PNUE), Genève, p 103
- Jacque Dermagne et al. (2006). Le changement climatique. Thinking group. Economic and Social Council, Academy of Sciences, Academy of Technology, Academy of Moral and Political Sciences (France). <http://www.changement-climatique.fr/blog-acces>. Accessed 24 Jan 2006
- Jnad I, Siba M (2006) Water and adaptation to climate change in the Arab region. Water Resources Dept., Arab Center for the Studies of Arid Zones and Lands, Damascus
- Josse J and Husson F (2012). *Journal de la Société Française de Statistique*. Vol. 153 No. 2 (2012)
- Kundzewicz ZW, Graczyk D, Maurer T, Pinskiw I, Radziejewski M et al (2005) Trend detection in river flow series: 1. Annual maximum flow. *Hydrol Sci J* 50:1–810. <https://doi.org/10.1623/hysj.2005.50.5.797>
- Laborde JP (2013). *Éléments d'hydrologie de surface*. Support de cours. Professeur émérite à l'Université de Nice—Sophia Antipolis.
- Lon Presti R, Barca E, Passarella G (2010) A methodology for treating missing data applied to daily rainfall data in the Candelaro River Basin (Italy). *Environ Monit Assess* 160(1). <https://doi.org/10.1007/s10661-008-0653-3>
- Maracchi G, Sirotenko O, Bindi M (2005) Impacts of present and future climate variability on agriculture and forestry in the temperate regions: Europe. *Clim Chang* 70(1-2):117–135
- Marvel K, Biasutti M, Bonfils C, Taylor KE, Cook YKABI (2017) Observed and projected changes to the precipitation annual cycle. *J Clim Am Meteorol Soc* 30:4983–4995. <https://doi.org/10.1175/JCLI-D-16-0572.1>
- Meddi M, Assani AA, Meddi H (2010) Temporal variability of annual rainfall in the Macta and Tafna catchments, Northwestern Algeria. *Water Resour Manag* 24(14):3817–3833
- Meddi H, Meddi M, Assani A (2014) Study of drought in seven Algerian plains. *Arab J Sci Eng* 39(1):339–359
- Mostefa-Kara K (2008). *La menace climatique en Algérie et en Afrique*. Hydra (Algérie): Editions Dahlab, 384 p.
- Mutin G (2011) *L'eau dans le monde arabe: menaces, enjeux, conflits*. Ellipses, Paris 176p
- Noughabi JM (2011) Outliers, definition and application. *Student J Stat* 9(1):1–16
- Ogburn, Stephanie Paige (2013). Climate change is altering rainfall patterns worldwide. *Sci Am*. ISSN: 0036-8733.
- Pardi F, Gascuel O (2012) Combinatorics of distance-based tree inference. *Proc Natl Acad Sci U S A*. October 9, 2012 109(41):16443–16448
- Pearson K, (1901) LIII. *Philosophical Magazine Series* 6 2 (11):559–572
- Raziei T, Daryabari J, Bordi I, Modarres R, Pereira LS (2014) Spatial patterns and temporal trends of precipitation in Iran. *Theor Appl Climatol* 115:531–540. <https://doi.org/10.1007/s00704-013-0919-8>
- Rong Y (2011). *Practical environmental statistics and data analysis*. ILM Publications, SA Trading Division of International Labmate Limited. Pp 223–226.
- Şen Z (2008) *Wadi hydrology*. Taylor and Francis Group, CRC Press, Boca Raton, p 347
- Şen Z (2013) Desertification and climate change: Saudi Arabian case. *Int J Glob Warm* 5(3):270–281
- Şen Z, Al Alsheikh A, Alamoud ASAM, Al-Hamid AA, El-Sebaay AS, and Abu-Risheh AW (2012). Quadrangle downscaling of global climate models and application to Riyadh. *J Irrig Drain Eng* © ASCE/OCTOBER 2012”.
- StatSoft France (2003). STATISTICA software, version 6. [www.statsoft.com](http://www.statsoft.com).
- Stockton CW (1988). Current research progress toward understanding drought. In: *Sécheresse, gestion des eaux et production alimentaire*. Mohammédia: Imprimerie Fédala, p. 21–35.
- Sultan B, Guan K, Kouressy M, Biasutti M, Piani C, Hammer G, McLean G, Lobell D (2014) Robust features of future climate change impacts on sorghum yields in West Africa. *Environ Res Lett* 9:104006. <https://doi.org/10.1088/1748-9326/9/10/104006>
- Taabni M. et El Jihad M. (2012). Eau et changement climatique au Maghreb: quelles stratégies d'adaptation?, *Les Cahiers d'Outre-Mer* [En ligne], 260 | Octobre–Décembre 2012, mis en ligne le 01 octobre 2015, consulté le 06 mai 2013. URL: <http://com.revues.org/6718>; <https://doi.org/10.4000/com.6718>.
- Turki I, Laignel B, Massei N, Nouaceur Z, Benhamiche N, Madani K (2016) Hydrological variability of the Soummam watershed (Northeastern Algeria) and the possible links to climate fluctuations. *Arab J Geosci*. ISSN 1866-7511 9(6). <https://doi.org/10.1007/s12517-016-2448-0>
- Yang R (2012). A hierarchical clustering and validity index for mixed data. Graduate theses and dissertations. Paper 12534. P6.