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THE RECENT CLIMATE CHANGE IN ALGERIA (NORTH AFRICA)

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Abstract

In order to determine to what extent the climate change affects the temperature and rainfall recorded on the southern coast of the Mediterranean basin, a trend analysis has been proposed. This study is released by the calculation of the reduced average index and on the chronological graphic method of information processing - MGCTI - of "Bertin Matrix" type. Data analysis shows a continual increase of the temperatures since the beginning of the years '80 of the last century for the minimum temperatures and since 1987 for the maximum temperatures. These results also confirm the net slowdown of the warming tendency in this region of North Africa. For the rains, the same matrix highlights the extreme variability of this climate parameter, also a serious and long-lasting character of the climatic draughts and gradual returns towards more humid tendencies, observed since the beginning of the years 2000. This new tendency has been confirmed according to the last results of the recent agricultural campaigns of the years 2011/2012 and 2012/2013.

Keywords: Algeria, climate change, temperature trend, rainfall trend, rainfall returns.

1. INTRODUCTION

The climate change is nowadays recognized by most of the scientific community. In its last report, IPCC (IPCC, 2013) evaluated the mean tendency of the world temperature during the period 1880-2012 at 0.85° C with an uncertainty ranging between 0.65° C and 1.06° C. The growth during the last decade (2003-2012) was +0.78° C (for a minimum of 0.72° C and a maximum of 0.85° C). Year 2012 is considered the 36th consecutive with a temperature growth worldwide, with a warming evaluated at 0.57° C (according to the calculation of the deviations of the continental and oceanic temperatures set by the National Climatic Data Centre (NCDC) for the period 1900-2012 (AonBenfielf, 2013). Along the Southern Coast of the Mediterranean Basin, the temperature growth is in line with the situation worldwide. Thus, the already quoted year is part of the warmest years recorded in Tunisia since 1950 (OMM, 2013 a). The growth of the minimal temperatures (Tn) is however more obvious in this part of North Africa (Nouaceur et al, 2013, 2014, Donat et al, 2013).

Whereas on a global scale the rise in temperatures is doubtless, the evolution of the rainfall worldwide is much more varied in space and time. Despite this parameter, and considering the rise in temperatures, a probable increase in precipitations is expected. Indeed, the acceleration of the hydrological cycle under the effect of the high temperatures could trigger more precipitations and evaporation (OMM, 2013 b). The results of different studies regarding the evolution of the rainfalls also show that the climate change has resulted in an intensification of the precipitations and a recurrence of the extreme events (more perceivable for the last decennia 1991-2010, OMM, 2013 b) (New et al, 2001, Christensen et al., 2007).

The Mediterranean area is acknowledged today as a "hot spot" area of the climate change. According to the results of different forecast models, it should witness, until 2100, an average temperature growth of 3-4° C, rainfall decrease and intensification of the extreme events (PNUD, 2009). The combined effect of the climate change and the anthropic impact would trigger a lack of water for about 290 million people. According to Mediterranean Environmental Technical Program (METAP, 2007), the Middle East and North African (MENA) region would be seriously affected, since most of the countries situated in this area (except for Iran and Iraq) have reached the hydro stress threshold (1700 m^3 renewable water per inhabitant per year). At the same time, Algeria and Tunisia, which are part of the MENA area have reached an absolute level of their lack of water.

This return of the rains over the central Magreb, if confirmed, could mark the end of several decennia of recurrent droughts (Nouaceur et al, 2013, 2014), and forecasts a potentially durable return to the "normal". This hypothesis is supported by the highlighting of the impact of different climatic oscillations on a global scale (North-Atlantic-Oscillation; El Niño Southern Oscillation) on all the continents and especially on the African continent (Sebbar et al, 2007, López-Moreno et al., 2011). The forecasts vary from one model to the next, yet a growth in precipitations and a multiplication of the extreme climatic events could set in within this global dynamics of climate change (IPCC, 2013).

2 DATA AND METHODS

The objective of this paper is to analyze the rainfall and temperature trend for over forty years of measurements over a wide band of northern Algeria. Twelve stations that provide a common measurement period were selected for this study (table 1 and figure 1). The data have been obtained from the national meteorological networks national meteorology office (ONM, 2013, http://www.meteo.dz/) for Algeria, and have been supplemented by information collected on the "NOAA, National Climatic Data Center, 2013) " w*ebsite*" (http://www.ncdc.noaa.gov, http://www.ncdc.noaa.gov).

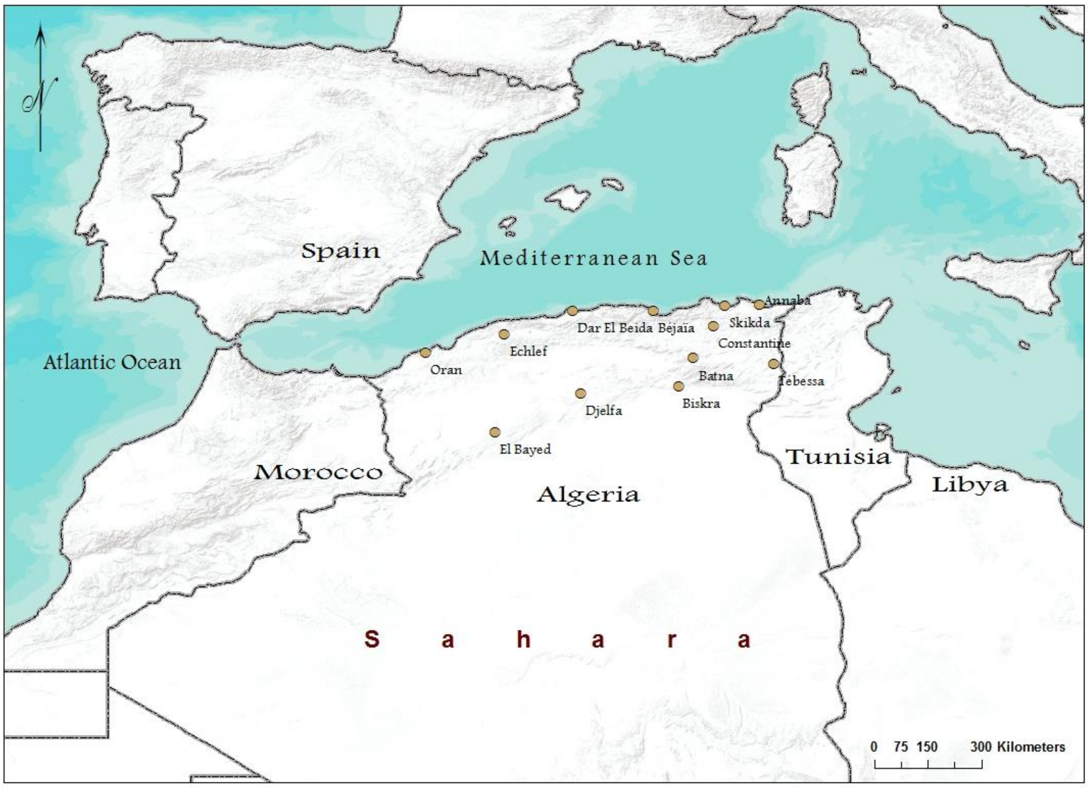

Figure 1. Map of study area localization

Table 1. Features of the stations used for this study

Stations	***Longitude***	***Latitude***	***Altitude***
Annaba	7,49	36,5	8
Batna	6,19	35,45	822
Bejaia	5,04	36,43	1,74
Biskra	5,44	34,48	82
Constantine	6,37	36,13	685
Dar El Beida	3,13	36,41	25
Djelfa	3,23	34,2	1180
Echlef	1,2	36,13	143
El Bayed	1	33,4	1341
Oran	-0,36	35,38	90
Skikda	6,54	36,53	1,3
Tébessa	8,07	35,25	820,47

In order to determine the rainfall and temperature trend, we have used the chronological graphic method of information processing (MGCTI) of "Bertin Matrix" type (Nouaceur et al., 2013). This method aims first to analyze the rainfall distribution in space and in time and second to determine the changes in rainfall cycles.

A classification per year relative to limit values (Q_1, Q_2, median, Q_3 and Q_4) is performed for all stations and for the full time series (Table 1). The years with cumulative rainfall or lower than the limit value of 1 (Q_1) are considered very dry or very rainy. Those were situated between Q_1 and Q_2, that are considered dry. The years having a rainfall height between the second quintile and the averages are normal with a dry trend. Between the median interval and Q_3, the years are normal with a trend associated with a wet weather. Between Q_3 and Q_4, years are classified as wet. Finally, the years with cumulative rainfalls higher than Q_5 are considered as very wet.

After this first stage, a recoding of values through a range of colors is to be done (the varying color depending on the position of the rainfalls cumulative compared to the limit values). This first analysis is followed by a procedure for reordering (permutations of columns) in order to obtain a classification showing a homogeneously colored structure (according to Bertin matrix). This procedure allows us to visualize the evolution of the rainfalls according to two dimensions (in space and time).

To determine the ruptures and the characteristic periods, a second procedure is to be performed. It is to assign a number ranging from value 1 (very dry year) to value 5 (very humid) following the characteristics already determined and allocated to each year. The sum of numbers of all stations per each year is drastically reduced, allowing obtaining an index which varies from +1.80 for a very humid year to -1.80 for a very dry year. The result is projected on a graphic to show first the rainfall variability on a regional scale and second to determine the dates of breaks and changing trend.

Table 2. The dispersion parameter calculated for the rainfalls and the temperature (1970-2013)

Station	Oran	Dar El beida	Annaba	Skikda	Béjaïa	Echlef	Biskra	El Bayed	Djelfa	Tébessa	Constantine	Batna
Tx												
Min	22,10	21,58	21,69	20,80	20,86	24,19	26,07	18,93	18,68	20,29	19,28	18,04
Q1	22,87	22,72	22,40	21,48	21,83	25,00	27,04	19,95	20,03	21,48	20,83	19,75
Q2	23,22	23,22	23,00	21,85	22,28	25,23	27,70	20,75	20,55	22,12	21,68	21,11
Me	23,51	23,57	23,14	22,00	22,49	25,60	27,97	20,90	20,70	22,37	22,06	21,69
Q3	23,70	23,90	23,32	22,02	22,90	25,91	28,29	21,07	20,98	22,52	22,13	22,48
Q4	24,25	24,39	23,70	22,48	23,20	26,21	28,60	21,63	21,25	23,18	22,90	23,10
Max	24,80	25,03	24,36	23,43	23,70	26,81	29,50	22,20	22,02	24,30	23,42	24,10
Average	23,51	23,56	23,14	22,05	22,52	25,62	27,89	20,85	20,67	22,33	21,84	21,64
Tn												
Min	10,92	10,78	11,42	11,84	12,23	11,06	14,90	7,51	6,78	6,78	8,13	6,63
Q1	11,47	11,35	11,88	12,66	12,66	11,82	15,98	8,12	7,50	8,09	8,71	7,38
Q2	11,98	11,65	12,38	14,27	13,29	12,70	16,48	8,88	8,15	8,90	9,20	7,89
Me	12,23	11,87	12,53	14,71	13,47	12,93	16,73	8,90	8,45	9,04	9,38	8,08
Q3	12,53	11,91	12,70	14,87	13,60	13,13	16,88	9,11	8,56	9,48	9,53	8,30
Q4	13,06	12,50	13,17	15,33	13,89	13,70	17,20	9,70	9,10	10,06	10,27	8,63
Max	13,38	13,16	13,76	16,11	14,64	14,73	17,62	10,48	9,70	11,03	10,73	9,11
Average	12,25	11,88	12,57	14,28	13,36	12,92	16,60	9,01	8,32	9,04	9,44	8,06
R												
Min	171,70	280,00	409,00	491,60	320,00	213,50	47,00	106,70	152,40	199,00	253,30	159,20
Q1	259,20	456,80	515,00	606,00	615,00	297,50	64,30	212,40	239,55	271,20	386,60	224,10
Q2	320,70	577,00	584,00	655,83	740,60	334,00	93,00	265,10	297,50	346,70	464,57	287,00
Me	350,70	683,52	614,60	729,80	780,80	361,00	125,98	270,90	321,48	370,35	485,20	307,55
Q3	404,20	717,50	662,44	754,00	833,00	419,10	133,61	278,52	341,20	389,96	514,20	337,05
Q4	439,10	797,80	773,00	854,40	969,20	485,10	190,30	332,20	394,70	454,90	662,90	415,19
Max	609,00	1169,00	1126,00	1148,20	1373,41	577,11	295,00	546,57	512,70	646,60	868,20	596,80
Average	355,12	648,95	652,67	735,23	800,60	384,60	129,45	278,56	323,23	380,44	523,58	326,14

3. RESULTS

3.1. Towards increasingly warmer conditions?

A clear rising tendency since the beginning of the 1980s for the temperatures was recorded on the coast. Evolution of the temperatures for the last over 40 years of measures shows a confirmed rise since the middle of the ‘80s. The regional indexes eloquently show a clear rise in the chronological series beginning with the 1982 for the minimum temperatures and since 1987 for the maximum temperatures (Fig. 2).

For the minimum temperatures, the matrix (MGCTI) also shows a structured organization and a progressive evolution of the values.

Four characteristic periods mark the evolution of the minimum temperatures:

- 1970-1981, with a predominance of number of humid and very humid years (one can note, therefore, five years with a frequency of 100% and three years of over 80%). The year 1981 differs from this tendency because slightly over 66% of the stations recordings, during this year, a normal year;
- 1982-1990 mark the start of the climatic warming noticed in Algeria. The number of the hot and very hot years increased especially for the last four years of the period;
- 1991-1993, with a return of the humid and very humid conditions, this being noticed for this period. Conditions of that type are characteristic for all stations in 1991 and 1992;
- 1994-2013, that was hot years increase in number for all of the stations. During the years 1994, 1999, 2003, and 2006, all the stations respected these particular conditions. Finally, beginning with 2004, one can note a clear slowdown of the climatic warming observed.

For the maximum temperatures, the same fluctuations can be found as for the minimum values. Also the matrix (MGCTI) highlights an organization in four main stages.

- 1970-1986, with a preponderance of the humid or very humid years;
- 1987-1990, associated with a start of warming for the maximum temperatures;
- 1991-1993, a new period of humid and very humid conditions (one can note 100% stations with these conditions in 1991);
- 1994-2012, with an important increase of the hot years (for 7 years, all the stations were characterized by a frequency of 100% associated to this category).

Therefore, an evolution including 4 clear distinct phases, oscillating between warming and cooling marks the temperatures. The evolution of the maximum and minimum temperatures seems comparable as a whole. The first cool period is characteristic for the year 1986 for the maximums, while it only goes up to 1981 for the minimums. Beginning with 1994, the rise seems even more evident for the maximums (the regional indexes indicate a more important number of stations affected by these new conditions - the limit 0.9 corresponding to 50% and indicating partial heat - being exceeded several times since 1999). Finally one can note as well for the maximums a net fall off of the values recorded between 2004 and 2009.

3.2. Towards the end of the climatic droughts?

Graphical matrix MGCTI shows an organization of the rainfall trends according to three characteristic periods:

- In a first stage, strongly variable, between 1970 and 1986. No clear climatic trend can be distinguished for this period. All the stations under analysis presented an almost equal share of the different categories of rainfalls per year, humid and very humid (40%), dry and very dry (39.50%) and almost normal (20.5%). The regional index is negative for over 47% of the years compared to 52.94% for the positive values. The remarkable fact about this period is certainly the strong inter-annual oscillation between dry years and humid years. In fact, only a succession of three humid years (1971-1973) can be noticed for the beginning of the series. During the rest of the period mentioned, the reversals of trend (dry years, humid years) occur over a maximum of two successive years.
- The second stage begins starting with 1987 and ended in 2002. It was marked by a dry tendency because the regional index negative for about 68% of this period compared to 32% for the negative values. The persistence of the draught conditions never exceeded three years consequently. The extreme negative values for this dry stage were recorded in 1989 (-1.68), 2000 (-1.87) and 2001 (-1.49).
- The last period of this rainfall series (2003-2013) with approximately 82% of the years having a positive regional index was considered as humid. For the entire series under analysis, this last stage stands out by a series of 7 years (2007-2013) in a row with positive regional recordings.

The return of the rains has been confirmed in Algeria by the results highlighted by the MGCTI Matrix. These rains are however increasingly intense and often cause floods and inundations. This new trend has been confirmed by the analysis of the evolution of the number of the severe perturbations (meteorological perturbations of a severe type, RR ≥ 30 mm/24 h), that hit Algeria (Figure 3). One can notice on this figure a clear intensification of these phenomena beginning with the year 2003. During the year 2013, the national meteorology (http://www.meteo.dz) has recorded a total of 34 perturbations, the most important number observed during these last 20 years.

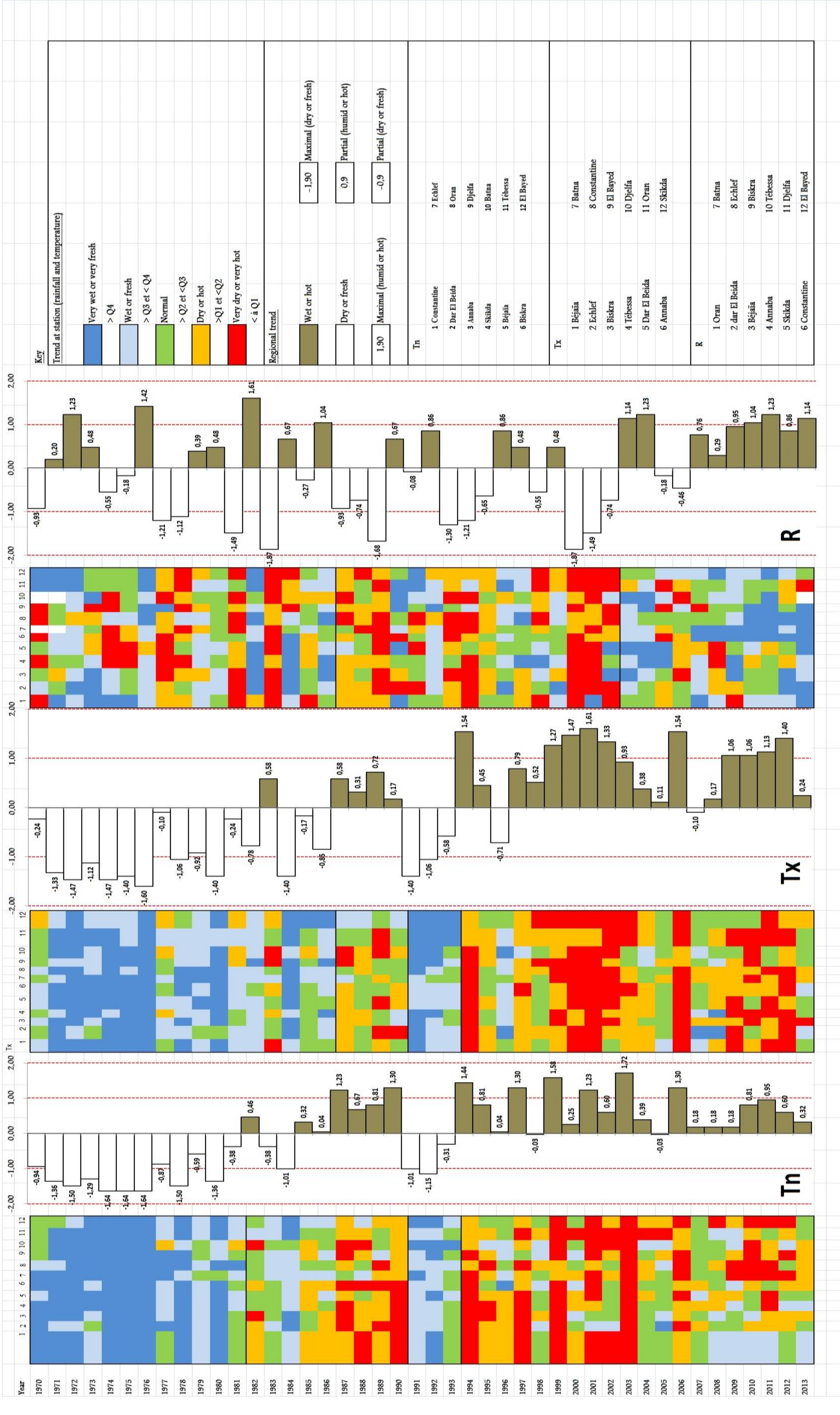

Figure 2. The graphic chronological data processing method (MGCTI) applied for rainfall and for temperature (1970-2013)

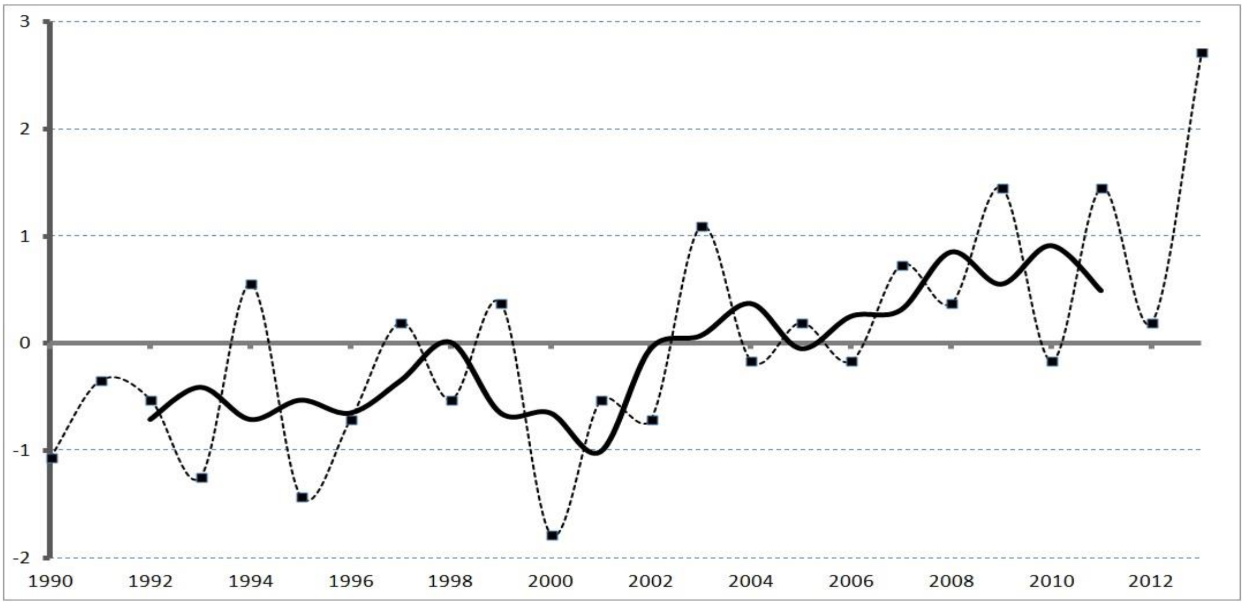

Figure 3. Reduced centered deviations of the severe perturbations that hit Algeria in 1990-2013 (meteorological perturbations RR ≥30 mm/24 h)

4. CONCLUSIONS

The analysis of the thermal and pluviometric data recorded in this large area of the southern coast of the Mediterranean Basin shows a continual increase in the temperatures accompanied by a decrease in intensity over the last years of the series under analysis. For the rains, their differing trend from the character of the Mediterranean climate is the first element highlighted. The analysis of the available data brings to light as well the importance of the great period of drought (1987-2002) and beginning with this last year the return towards more humid conditions which despite the persistence of an extreme variability (short return of the dry and very dry years noticed, for example, in 2005 and 2006).

In this regard, the rise in temperatures in this region is according to the forecasts of climate models, while the return of rains over southern coast of the Mediterranean Basin is not. These facts also are not according to the results published by Tramblay et al. in 2013 (strong tendency towards a decrease of the rainfall series). The signs of changes are very significant over the last years in all this region of North Africa. So, in Algeria, the agricultural campaign 2008-2009 was described as very satisfactory and the cereal production registered during the following years (2009-2010) constitute a record never equaled, with its 61.2 millions quintals. The hydrological situation is also satisfactory, if we take into consideration the publications of the Ministry of Agriculture (an unprecedented filling of the dams for 2010-2011 of around 72% and for 2012-2013 of 85.4%, levels never reached before). Morocco also respects this same trend for 2013. So, the average rainfall was 450 mm, which means a 20% additional rainfall compared to a normal year (according to the Ministry of Energy, Mines, Water and Environment, 2013). In the same time, the agricultural campaign of this last year assured a new record of cereal production, evaluated to 97 millions of quintals (Lahrach, 2013).

These facts therefore bring hopes for a beginning of a new climate stage, signaling an end of the extreme conditions of the past.

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