CLIMATE CHANGE DETECTION WITH EXTREME WEATHER FACTORS CONCERNING ALGERIA

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Abstract

In order to detect if our area is affected by a climatic tendency, a great number of indices was calculated on the basis of daily data from the Algerian meteorological service network. The maps analysis of the indices trend calculated using RclimDex, illustrated a significant change in the climatic parameters. Thirty statistical indices were selected among the twenty seven proposed by ETCCDI team. The calculation of these indices is based on maximum and minimum daily temperatures and precipitations data. The temperature indices showed warming tendency. Unexpectedly, we noticed a positive trend with the precipitation indices over the north ouest of Algeria.

Keywords: Climate change, RclimDex, Climatology, NOAA Data

Introduction

Climate change indices are developed in several centers and by many researchers. The purpose of the development of these indices is mainly the detection of climate change and homogeneity study. In 1995, the Intergovernmental Panel on Climate Change (IPCC), in its second report confirmed that anthropogenic effects have significantly influenced the global change (IPCC, 1995). One of the resulted effects is the increasing in average global temperature of about 0.7°C since the second half of the last century (Nicholls et al., 1996 ; Parker et al., 2000). Lately, we observed our planet temperature increase reaching 0.85°C since the pre-industrial period ; The last three decades are "probably" the hottest recorded ones in the northern hemisphere for at least 1400 years (IPCC, 2014). This change in the average temperature may modify its probability distribution that can affect all ecosystems (Frich et al., 2002). The increase in the global average parameters does not necessarily occur everywhere on earth.

As with most of the climate studies, the major problem encountered is the low resolution of the meteorological observations network, the high percentage of missing data, the short period of working times of some weather stations and the metadata unavailability. All these constraints can complicate our work.

This study aims to investigate about recent changes in selected climate indices tendencies concerning Algeria and clarify, if changes occur in climate parameters, including temperature and precipitation, what is the magnitude of their tendencies? And what are the most affected regions in Algeria? For this purpose, the maximum weather stations of the National Meteorological Office network were used.

Knowing that all climatological study must start with the quality control and homogeneity of the time series. The work begins with (i) a description of the methodology used to test the quality of the data and the homogeneity study (Wang et al., 2010 ; Boris, 2014) of temperature and precipitation recorded in meteorological stations network of the "*Office National de la Méteorologie (ONM)*" using iki.dataclim package (Boris, 2014), then by (ii) a description of the indices selected from all calculated using the climdex.pic tool (Peterson, 2005 ; Sillmann et al., 2013a, b)

For illustration and spatial analysis, indices slope maps are drawn. The results of the analysis are discussed and some conclusions are obtained in order to confirm similar works done at larger scales (Frich et al., 2002 ; Alexander, 2006).

Methodology

The approach of this work is done by developing maps of climate change indices slopes. For doing this, we had two possibilities : (i) by representing the indices slopes in a map using the real observation position and compare them in space, or by plotting the equal values lines of the indices slopes. However, the second approach requires a larger number of observation points. Finally, we adopted the first method for representing the indices.

Data selection

For this work, initially, all weather stations of the Algerian meteorological service network are selected (Figure 1.a) but only data sets having at least 20 years of recorded data, (Figure 1.b). Generally we also used the criteria according to Frich et al., (2002) that a year is considered as missing if it contains more than 10% of daily missing data or more than 3 months in the year have more than 20% missing data.

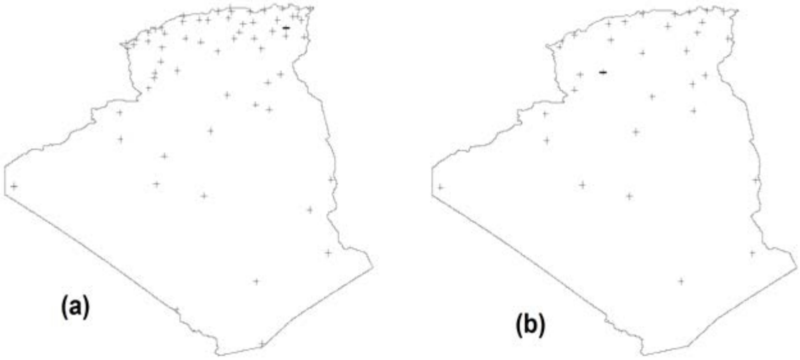

Figure 1 :The Algerian Meteorological Service Network (a) and the selected network according to the selection criteria (b).

Given that the selection criteria differ from one country to another, depending on data availability and quality of the observation network, it is useful to note that we have not chosen the most rigorous selection criteria. Note also that data availability in some weather station is low and sometimes not adequate for this type of work. Finally, about thirty weather stations covering most climatic regions in the country are considered.

The climate elements as maximum temperature, minimum temperature and precipitation are used for the calculation of the indices they are probably the most felt by living beings.

ETCCDI Indices and selection

The joint CCl/CLIVAR/JCOMM Expert Team (ET) on Climate Change Detection and Indices (ETCCDI) has a mandate to address the need for the objective measurement and characterization of climate variability and change by providing international coordination and helping organizing collaboration on climate change detection and indices relevant to climate change detection, and by encouraging the comparison of modeled data and observations. Issues being addressed include for NMHSs materials to guide the calculation and use of climate change detection indices and climate data homogenization, improvement.

Among all indices used by climatologist and recommended by the Expert Team Monitoring on Climate Change Detection and Indices (ETCCDI), we used 30 indices calculated using the new version of RclimDex tool. The selected indices can be subdivided into four categories depending on the used parameters in order to show the intensity and duration of changes in temperature and precipitation (Table 1,2,3 and 4).

Table 1 : Rainfall indices summary

#	Common name	Indice	Description	Units
1	Consecutive dry days	CDD	Maximum number of consecutive days with RR<1mm	days
2	Consecutive wet days	CWD	Maximum number of consecutive days with RR>=1mm	days
3	Annual total wet-day precipitation	PRCPTOT	Annual total PRCP in wet days (RR>=1mm)	Mm
4	Simple daily intensity index	SDii	Annual total precipitation divided by the number of wet days (defined as PRCP>=1.0mm) in the year	mm/day
5	Max 1-day precipitation amount	RX1day	Monthly maximum consecutive 1-day precipitation	mm
6	Max 5-day precipitation amount	RX5day	Monthly maximum consecutive 5-day precipitation	mm
7	Extremely wet days	R99p	Annual total PRCP when RR>99^{th} percentile	mm
8	Very wet days	R95p	Annual total PRCP when RR>95^{th} percentile	mm
9	Number of heavy precipitation days	R10mm	Annual count of days when PRCP>=10mm	days
10	Number of very heavy precipitation days	R20mm	Annual count of days when PRCP>=20mm	days

Table 2 : Minimum temperature indices summary

#	Common name	Indice	Description	Units
11	Cool nights	TN10p	Percentage of days when TN<10th percentile	days
12	Warm n-"ights	TN90p	Percentage of days when TN>90th percentile	days
13-14	Tropical nights	TR20 et TR25	Annual count when TX (daily maximum) > 20°C or 25ºC	days
15	Frost Days	FD0	Annual count when TN (daily minimum) <0ºC	days
16	Tmin mean	TN mean		°C
17	Min Tmin	TNn		°C
18	Max Tmin	TNx		°C
19	Cold Spell Duration Indicator	CSDI	Annual count of days with at least 6 consecutive days when TN<10th percentile	days

Table 3 : Maximum temperature indices summary.

#	Common name	Indice	Description	units
20	Summer days	SU25 &SU35	Annual count when TX(daily maximum) > 25ºC or 35°C	days
21	Cool days	TX10p	Percentage of days when TX<10th percentile	days
22	Warm days	TX90p	Percentage of days when TX>90th percentile	days
23	Warm spell duration indicator	WSDI	Annual count of days with at least 6 consecutive days when TX>90th percentile	days
24	Frost Day	ID0	Annual count when TX(daily maximum)<0ºC	days
25	Annual Count When TX<20°C	ID20	Annual count when TX (daily maximum)<20ºC	days
26	Max Tmax	TXx		°C
27	Mean Tmax	TX mean		°C
28	Min Tmax	TXn		°C

Table 4 : Summary of the combined minimum and maximum temperature indices.

#	Common name	Indice	Description	Units
29	Diurnal temperature range	DTR	Monthly mean difference between TX and TN	ºC
30	Growing Season Length	GSL	Annual (1st Jan to 31st Dec in NH, 1st July to 30th June in SH) count between first span of at least 6 days with *TG>5ºC and first span after July 1 (January 1 in SH) of 6 days with *TG<5ºC	Days

*TG= T_{ij} is the mean temperature on day i in period j

Indices calculation

RclimDex offers the calculation of the indices on a daily basis, but some of them are based on monthly data. The monthly indices are calculated if more than 3 days of the month are not missing, while annual values are calculated if the number of missing days by year does not exceed 15 days and the threshold is calculated if we have at least 70% of the data. Concerning the length of the sequences (wet or dry), if a sequence overlaps two years, it is counted for the year ending this sequence (Zhang *et al., 2004*).

Discussion of Results

Temperatures indices

Minimum Temperature (TN)

The TN10p index gives the percentage of days when minimum temperature (TN) <10th percentile and representing cool nights. The TN10p slope map (Figure 2.a), shows that 99.9% of the observations have a decreasing trends, this reflected that the minimum temperatures which occur at the end of nights tend to rise, meaning that the nights in Algeria are warming.

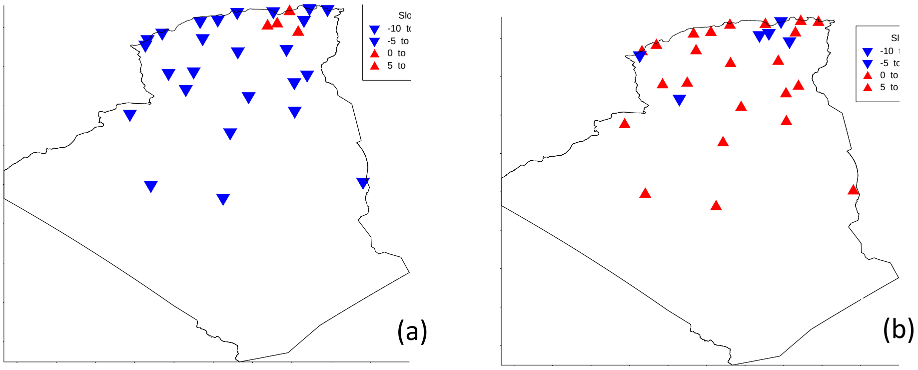

Figure 2 : Map trends of TN10p (a) and TN90p Indices (b).

However, TN90p (Figure 1.b), TR20 and TR25 indices (Figure 3.a and b), shows that more than 99% of the observations point have an increasing trends which is by definition, are respectively "warm nights" and "tropical nights (20°C and 25°C**)**". These indices have positives trends for more than 99% of the considered weather stations, and then confirm warmer nights except the north East region.

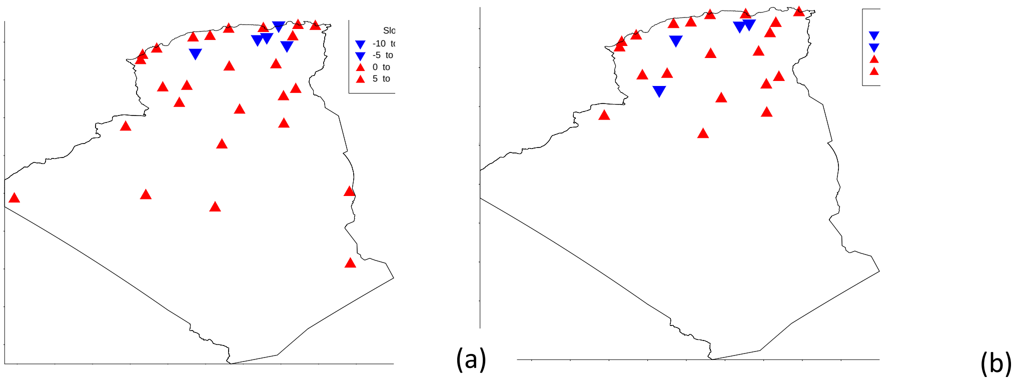

Figure 3 : Trends maps of TR20 (a) and TR25 Indices (b).

The trends maps of the Max, Min and Mean of the minimum temperatures (not illustrated) shows an increasing in more than 99% locations in Algeria and confirm warmer nights. The frost days represented by FD0 indice, gives the annual count when (daily minimum temperature is less than 0ºC and the FD0 slope map (Figure 4.a), shows that the number of frost days in the most parts of Algeria is increasing but decrease in the Western region. The trend map of Cold Spell Duration Indicator (CSDI) indice shows an increasing in 40 % and a decreasing in 60%, it means that cold spell duration is diminishing in more than 60% over Algeria (Figure 4.b).

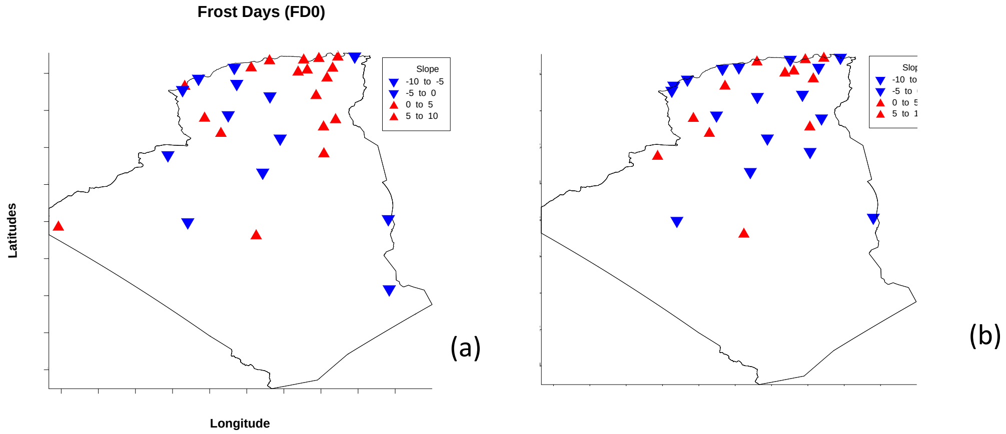

Figure 4 : Trend maps of the number of frost days (a) and the cold spell duration (b).

Maximum Temperature (TX)

Figure 5, summarizes the results of indices based on the maximum temperatures, knowing that in normal weather conditions, the maximum temperature occurs during the day time. Cold days represented by TX10p index are shown in figure 5.a, where all of observation locations have an index with a decreasing trend, meaning that the number of cold days is decreasing over all Algeria. Warm days represented by TX90p (Figure 5.b) are increasing for all observation locations. This implies an increase in the number of hot days or the particular days with the same thermal characteristics of a summer day.

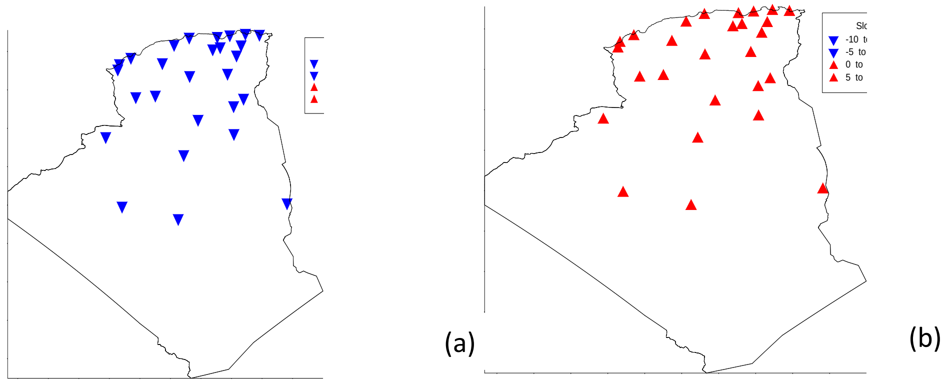

Figure 5 : Trends maps of the number of cold days (a) and the warm days (b).

In figure 6, we can see that 3 indices based on maximum temperature prove that days over all Algeria are warming more than in the past. The trend of summer days (SU25) and the Maximum temperature average (TMAXmean) indices (figure 6.a and b) are increasing over all Algeria. Meaning that days over the year are warming and became more likely to summer days. The trend map of the annual count when maximum temperature is less than 20°C (ID20), figure 6.c, shows a decreasing for this indice over all Algeria and confirm the warming of the days.

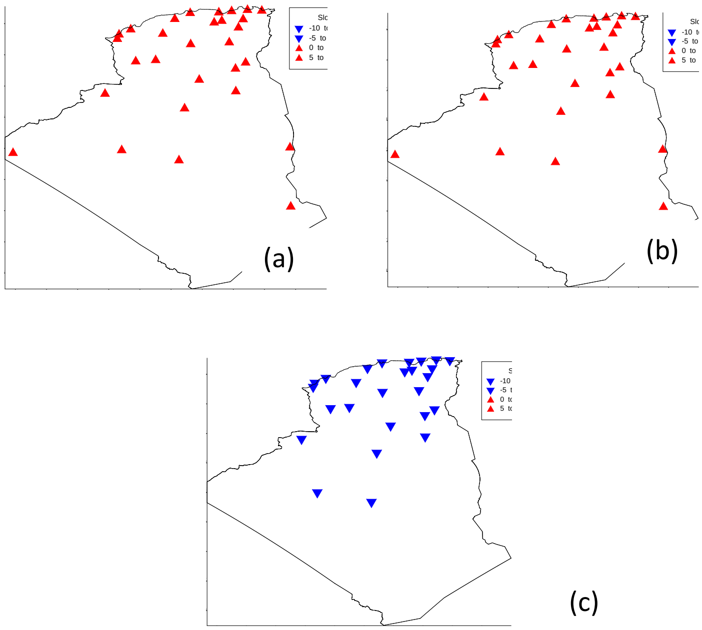

Figure 6 : Trends maps of the number of summer days (a), the average of Maximum temperature (b) and (c) the annual count when maximum temperature is lower than 20°C.

The trend map of warm spell duration indicator (WSDI) figure 7.a and monthly maximum value of daily maximum temperature (TXx) indices figure 7.b confirm the warming over Algeria. We can see in figures 7.a and 7.b that in all weather station locations, the indices are increasing. Meaning that the length of warm spell duration is increasing except for the costal North region.

TXx trend map divide Algeria on two regions, the North where the indice trend is decreasing and the South where it increasing. It means that extreme daly temperature is increasing in the Southern part and decreasing in the Northern.

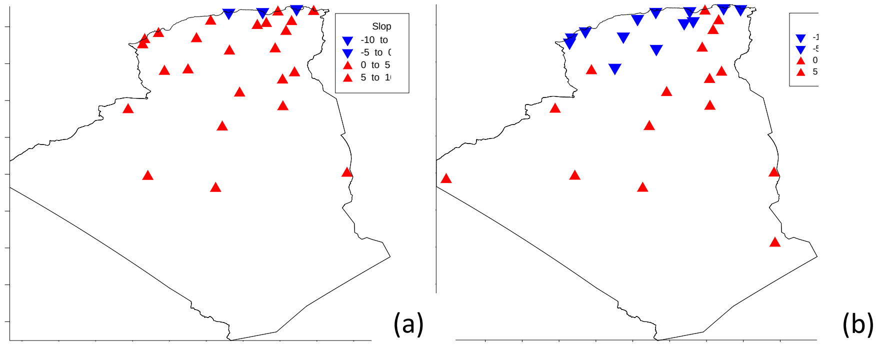

Figure 7 : Trends maps of warm spell duration indicator (a) and monthly maximum value of daily maximum temperature (b).

Minimum and Maximum Temperature

Indices which combine minimum and maximum temperature show that the indices based on Minimum and Maximum (DTR and GSL) are all increasing for at least 80% of the map area. The increasing results of the Growing Season Length (GSL) indice (Figure 8.a) which can be used in agronomy and botany sciences. The positive trend (Figure 8.b) of diurnal temperature range (DTR) can be interpreted as a shift of climate from the temperate to the semi-arid in the North and from the semi-arid to the arid in the South. The increasing of temperatures indices trend implies significant warming. All these interpretations confirm the results of Alexander (2006) and the work done with monthly data on a global scale by Jones et al., (1999) and on the regional level with daily data by Yan (2002).

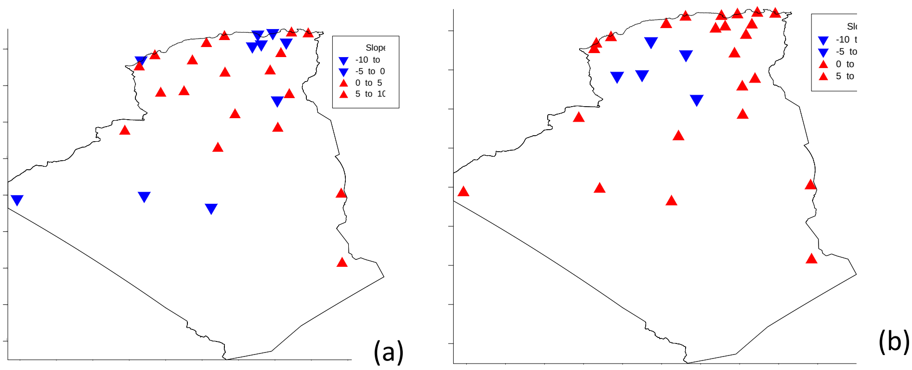

Figure 8 : Trends maps of growing season length (a) and Diurnal Temperature Range (b).

Precipitations

The analysis of the figures 9 proves that the observation of the annual total rainfall (PRCPTOT) and the consecutive Wet Days (CWD) are rising in the rainy regions principally in the North East with (figure 9.a). The trend of this indice is proportional to the annual amount of precipitation. The low rainy regions have negative trend, in the north region. All areas with high rainfall have important positive trend. This statement follows the same rule which govern the precipitation in the north part of Algeria up to latitude 32° N: "***The precipitation increases from the west to the east and also increases from the north to the south***".

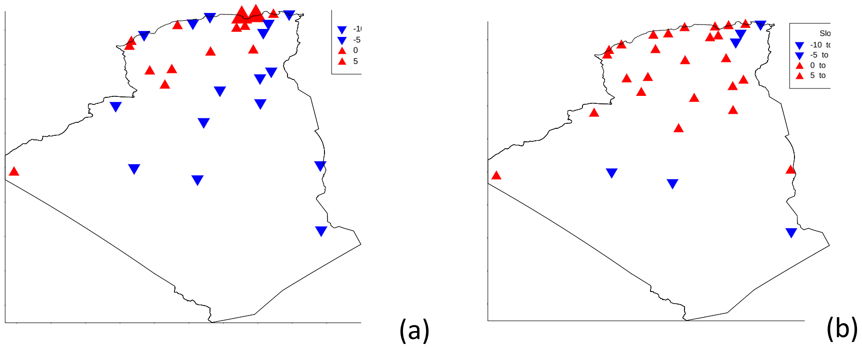

Figure 9 : Annual total precipitation (a) and Consecutive Wet Days (b).

Thus, all the indices on the map are located at the observations points, the interpretations cannot be generalized particularly those based on the precipitation parameter known with high variability in space and time within this type of climate (semi-arid and arid climate).

In this study we confirm the statement given in the 4th and 5th IPCC reports 2007 and 2014 that the positive global temperature trend is over all Algeria.

All indices based on precipitation confirm for Algerian rainy region what was said for the entire world (It is almost certain that rainfall events will become more intense" [IPCC, 2014]).

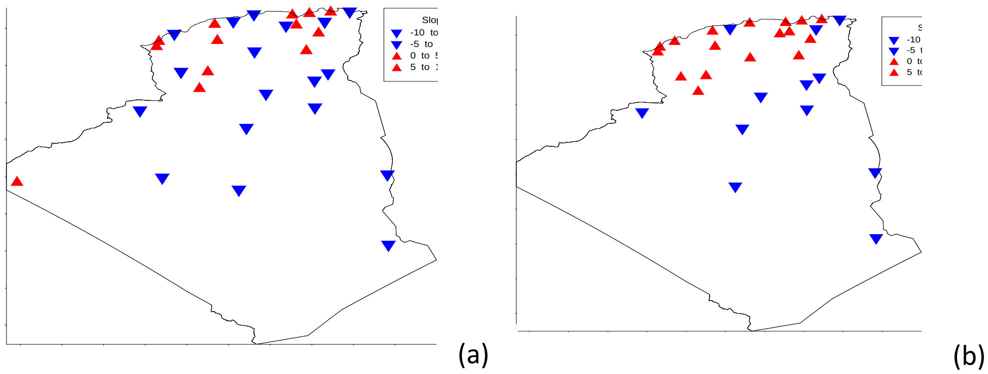

Figure 10 : Simple daily intensity index trend map (SDii) (a) and Number of days with very heavy precipitation (b).

Figure 10 shows that more than 50% of the weather stations in the north part of Algeria have an increasing of this indices and more than 90% records increasing of the number of days with precipitation amount is more than 20 mm/day, meaning that severe weather becomes likely in this region.

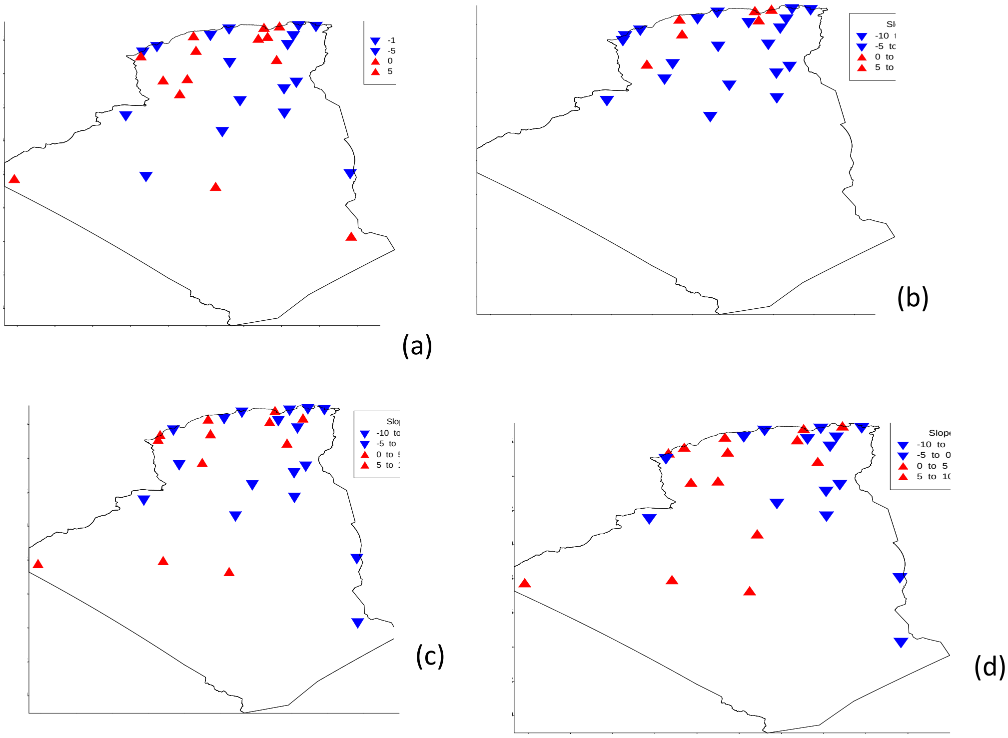

Figure 11 : Trend maps of (a) very wet days (R95p), (b) Extremely wet days (R99p), (c) max 1 day precipitation amount and (d) max 5 days precipitation amount indices.

The figures 11.a to d are confirming the installation of a climate change in our region with increasing of the number of occurrence of heavy rain, especially in the west part of Algeria.

Conclusion

The summary of maps analysis of the 30 climate trend indices calculated for Algeria, demonstrated a spatial coherence of a positive temperature trends. However, the proportion of weather stations with significant trends in rainfall indices is about 60 %. The mainly temperature indices have a warming trend; the frequency of hot days seems significantly increase and the frequency of cold days has decreased significantly. The trend of the TX10p (cool days) indice is decreasing in the majority of the observation points. Indices based on minimum temperature and the average daily temperature ranges have tendencies expressing the global warming for the study area. Extreme temperatures and thermal amplitudes are rising, which often results with dangerous summer heat waves and increasing of the number of days with heavy rain. Also, with the large variability in time and space of precipitation parameter, the mapping of the slopes of rainfall indices shows that this parameter is very difficult to study particularly in semi-arid regions. However the duration of the dry sequence in the year is decreasing for the west part. Though, in the southern regions we have low positive trends of the dry sequence duration, although it is important to note that the concept of dry sequence has not the same meaning for the northern and southern parts of Algeria. The annual rainfalls have significant positive slope for stations in western Algeria. The rising rainfall recorded in the west part of Algeria comes from instability precipitation and severe weather.

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