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Discussions

Spatial distribution of the daily precipitation concentration index in Algeria

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Spatial distribution of the daily precipitation concentration index in Algeria

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Abstract

In this paper, the spatial and temporal distribution of the daily precipitation concentration index (CI) in Algeria (South Mediterranean Sea) has been assessed. Forty-two daily rainfall series based on high quality and fairly regular rainfall records for the period from 1970 to 2008 were used. The daily precipitation concentration index results allowed identifying three climatic zones: the northern country, characterized by coastal regions with CI values between 0.59 and 0.63, the highlands, with values between 0.57 and 0.62 (average of 0.61), except for the area of Biskra (CI = 0.70), and the southern region of the country, with high rainfall concentrations, with values between 0.62 and 0.69. CI is an index related to the rainfall intensity and erosive capacity; therefore, this index has great interest for studies on torrential rainfall and floods.

1 Introduction

The rainfall analysis with daily resolution in Algeria is a subject of great interest. This type of analysis is justified by the presence of great environmental risks such as floods and soil instability in the Mediterranean, resulting from the high percentages of yearly total precipitation concentration distributed in a few very rainy days separated by long periods of drought (Martin-Vide, 1994) and poor temporal rainfall distribution in large areas of the western Mediterranean (Cortesi et al., 2012).

The interest is not only focused on climate, but also on the effect of heavy rainfalls on other areas of the environment and society. However, the importance of daily precipitation has not been sufficiently studied. Only a few papers on the statistical structure of precipitation with daily resolution have been published. For example, the study of the Mediterranean basin (De Luis et al. 1996, 1997; Martin-Vide, 2004; Sánchez Lorenzo and Martin-Vide, 2006; Benhamrouche and Martin-Vide, 2011, 2012; Cortesi et al. 2012; Coscarelli and Caloiero, 2012) and other studies worldwide such

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as in Iran (Alijani et al. 2008) and China (Zhang et al. 2009). Statistical analysis was performed to determine the relative impact of different classes of daily precipitation and an assessment of accumulated rainfall.

High daily concentration index (CI) values have been obtained in southeastern Peninsular Spain and the geographical proximity to our study area invites us to focus on the spatio-temporal daily rainfall distribution of forty-two meteorological stations evenly distributed over the entire Algerian territory (Fig. 1), with high rainfall records, which means that most of the days in a given period (14 245 days) are taken into account. The study period was from 1970 to 2008. Despite these choices, several stations had some shortcomings.

2 Method

The methodology applied in this study, proposed by Martin-Vide (2004); including the definition of daily precipitation concentration and index, will be illustrated by an example (Table 1 data from the Chlef station for the period from 1970 to 2008. These meteorological stations do not show high daily precipitation values and, therefore, their frequency distribution can be presented in a moderate-length table.

In the first column of Table 1, class limits are presented in ascending order and column two shows their midpoints. In the third column, named (Ni), the number of recorded precipitation days in each class, or absolute frequency, is listed. For example, in 39 years, 819 rainy days were recorded with variant amounts from 0.1 to 0.9 mm, and 407 rainy days represented amounts ranging from 1.0 to 1.9 mm, etc. The rainiest day had between 99.9 and 100.9 mm. Overall, there were 2753 rainy days. The fourth column represents cumulative frequencies of rainy days, named ($\sum N$), which is obtained by adding the absolute frequencies of all classes (the last value of this column is the same as the total number of precipitation days). The fifth column is the total precipitation for each Pi class, which is obtained by multiplying the corresponding Ni value (center of class or midpoint). The total accumulated rainfall named ($\sum Pi$), on the sixth column, are obtained by progressively adding up the values of the previous column, the value of the last class is the total precipitation of 13 958.5 mm recorded in the study period (1970–2008). The last two columns can be interpreted as follows: almost 1/3 of rainy day 29.75 %, with 0.9 mm or less, represents only 2.93 % of the total accumulated rainfall.

These results give the graphic representation shown in Fig. 2: the cumulative percentage of rainy days (next-to-last column of Table 1), ∑Ni (%) or X is plotted against the cumulative percentage of rainfall amounts (last column), Pi (%) or Y. Note that the resulting polygonal line is markedly exponential in the statistics and is called concentration curve or Lorenz.

The equidistribution line (the ideal case) represents a perfect daily precipitation distribution with all equal amounts. The concentration is a function of the relative separation from the equidistribution line, Fig. 2 shows the concentration curve or Lorenz of the Chlef station. It shows a remarkable separation and respective equidistribution line, which indicates significant daily precipitation concentrations. Therefore, the Chlef meteorological station is a region with average rainfall concentration. In the station there are 10 % rainiest days which represent 55 % of the total amount of precipitation (90 % of the days, after being sorted, account for 45 % of the total).

However, we can refine Lorenz or concentration curves of the Chlef meteorological station by replacing polygons by exponential curves (Jolliffe and Hope, 1996). The work of Riehl (1949), Olascoaga (1950) and Martin-Vide (2004) showed that such functions are of the kind

$$Y = aX\mathrm{e}^{bx} \quad (1)$$

With a and b as constants.

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Parameters a and b of Eq. (1) were determined by the least squares method, given by Eqs. (2) and (3)

$$\ln a = \frac{\sum x_1^2 \sum \ln y_1 + \sum x_1 \sum x_1 \ln x_1 - \sum x_1^2 \sum \ln x_1 - \sum x_1 \sum x_1 \ln y_1}{N \sum x_1^2 - (\sum x_1)^2} \quad (2)$$

$$b = \frac{N \sum x_1 \sum \ln y_1 + \sum x_1 \sum \ln x_1 - N \sum x_1 \ln x_1 - \sum x_1 \sum \ln y_1}{N \sum x_1^2 - (\sum x_1)^2} \quad (3)$$

Knowing that N is the number of classes

After determining the two constants a and b, the definite integral of the exponential curve between 0 and 100 shows the area under the curve (the abscissa and the ordinate 100), which is given by the formula below:

$$s = \left[\frac{a}{b} e^{bx} \left(x - \frac{1}{b} \right) \right]_0^{100} \quad (4)$$

Calculation of surface S' bounded by the exponential curve and the equidistribution line (difference between 5000 (triangle area) and the value of Eq. S4).

$$S' = 5000 - S \quad (5)$$

Calculation of the concentration index CI given by the following formula from Martin-Vide (2004):

$$\mathrm{CI} = S'/5000 \quad (6)$$

Note that the CI value is a fraction of S' and the lower surface of the triangle is bounded by the equidistribution line.

In the case of the Chlef station, the application of Eqs. (2), (3) and (6) gives the following results: $a = 0.036$; $b = 0.033$; $\mathrm{CI} = 0.59$ (The calculations were performed using software developed under *Delphi* (the Supplement).

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3 Results and discussion

Annual precipitation is usually quite low in Algeria. These low rainfall values do not let representing different rainfall extremes in the study area. In some parts of northern Algeria, values can reach 1.100 mm in the Skikda region, according to the National Meteorological Office (ONM), while in some regions of the extreme south-eastern Algeria (Illizi, Bbm, and Adrar) amounts lower than 20 mm are recorded.

The monthly, seasonal and annual rainfall variability is high in a large area of Algeria. As the annual precipitation, the variation coefficient (standard deviation times 100 divided by the average annual rainfall) is 20–40 % in most northern stations and more than 70 % across the southern part of the country. The spatial distribution of meteorological stations is not homogeneous. There are only few stations in mid and southern Algeria, but they are representative of the territory because these stations are located in a desert area (Table 2 and Fig. 4).

The exponential curves of a given type in Eq. (1) were calculated for 42 meteorological stations in Algeria, for the period from 1970 to 2008 (Table 3 and Fig. 5). Extreme values are: CI = 0.57 in M'sila (Mid-East Northern Algerian territory), an area influenced simultaneously by the Saharan climate and the Mediterranean climate; and CI = 0.70 in Biksra (Mid-Eastern Algeria) with characteristics of marked rainfall by the Saharan climate. Despite the minimal distance between the two stations, a significant difference is observed, with variation coefficient of 13 % from the surface exponentially compressed by the two stations and the equidistribution line. This means that the daily rainfall patterns are quite different.

Through the exponential concentration curves, the rainfall percentage contributed 25 % of the rainiest days, i.e. those with larger amounts were calculated. The results are presented in Table 3. Extreme rainfall values can be found in: Tindouf, with 79 % and M'sila, with 66 % (Table 3).

Note that in the first case, as in other stations (Illizi Assekrem and Bordj badji Mukhtar) in southern Algeria the fourth part of rainy days represent 75 % of total rainfall.

This leads to a marked uncertainty in terms of annual rainfall, considering the low number of rainy days per year obtained.

Any anomaly in atmospheric general circulation can greatly increase or reduce the total annual precipitation.

4 Regionalization of the concentration index CI in Algeria

4.1 Analysis of the geographical and spatial patterns of the daily concentration precipitation in Algeria

Whatever the variable or index analyzed; the spatial patterns of Algeria need to be studied to better understand this phenomenon. These studies are quite complex due to: (1) latitudinal position of Algeria between the Tropic of Cancer and the midlatitude, therefore, it has several climatic zones; (2) considerable variety of altitude, orientation and relief inclination.

The geographic and spatial patterns of daily rainfall concentrations in Algeria have been analyzed. The concentration indices (CI) values of Table 3 are shown in Fig. 5 through isopleths, which allows determining the spatial distribution of the daily precipitation concentration in a large part of Algeria. By analyzing the values obtained, three climatic zones can be determined. The first area in northern Algeria is characterized by coastal regions with concentration indices (CI) values ranging from 0.63 nearly identical to western Algeria (except for the Mestghanem region = 0.64) and center of the country up to 0.59 in the east (Annaba) and this is due to the proximity to the Mediterranean and the surrounding relief, whatever the flow direction, there is always formation of depression, so the presence of cyclogenesis. The increased baroclinic instability in saturated air is closely related to latent heat release, so to the development of convective phenomena. Moreover, during the rainy season, northern Algeria is affected by polar fronts, as they are oriented from north to east, which center is wetter than the western portion.

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The map analyzed presents considerable geographic cohesions and identifies the region of the most concentrated daily rainfall and intensity of the most critical and aggressive rains.

By analyzing the CI values in the highlands of the country, it was observed that the CI values ranged from 0.57 to 0.62 throughout the country (average of 0.61), except for the Biskra area, in which maximum CI value was reached (CI = 0.70), (Table 3 and Fig. 5). These highlands are generally affected by western disturbances following the orographic forcing that causes thunderstorms with heavy rainfall sometimes resulting in floods in some areas. The high Biskra value can be explained by the relief, which means that precipitations occur in the northern slope of the Aures, and are dried in its southern side.

The analysis of the southern region of the country shows that the CI values are higher than 0.62, (0.69 in Tindouf). This is explained by the lack of rains in that part of the country. The lack of rains in the southern region of the country is due to the infiltration of cold air or to wet air, which ascend from low latitudes. The proximity of the Atlantic Ocean allows the maritime air masses to reach the Tindouf area and, in this way, it allows some synoptic perturbations that affect this region. The rainy season in the southern part of the country is summer. This is due to the warm air that ascends due to the adiabatic expansion in the Hoggar. This is often the reason for the occurrence of heavy rains that cause droughts in a relatively short period of time.

This is explained by the lack of rainfall in this part of the country, rare rains, which are recorded in the southern region of the country, are due to infiltration of cold air or upwelling of moist air from lower latitudes. The proximity of the Atlantic sometimes allows maritime air masses to reach the Tindouf's area and thus causes some synoptic disturbances in this region. The rainy season southern region of the country is summer and this is due to the upwelling of warm, moist air, which by adiabatic expansion of the Hoggar, often causes heavy rainfall and flooding in a relatively short time.

In the coastal areas of the country or mid and western regions, rains are more or less regular (Mediterranean perturbations produce high daily concentrations), whereas

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in the eastern region, daily rains are more regular. In general, daily precipitation is more regular in highlands. Towards the south, rains are aggressive and the total daily precipitation can only be equal to the total yearly.

4.2 Study of correlation between the concentration index and the parameters study

The values of the Pearson's correlation coefficient, Spearman's Rho and Kendall's tau-b were calculated respectively for each pair of variables (Table 4), which show that the correlation is significant at the respective significance $\alpha = 0.01$ and $\alpha = 0.05$. Indeed, the correlation between CI and the annual precipitation (P) is significant and negative, and a high value of about -0.43 (P value < 0.01) is obtained for the Pearson's correlation coefficient (i.e. the rainfall concentration on a small number of rainy days is apparently greater in areas with low annual concentrations). However, the correlation between CI and the annual variation coefficient (VC) is significant and positive: 0.54 (P value < 0.01). This result seems related to the rainfall behavior on an annual scale and on a daily scale, further supporting the hypothesis that a very small number of rainy days can change the yearly rainfall behavior (wet or dry). On the annual number of rainy days (N) and CI, they are negatively related (-0.53) and the correlation is significant at the level of 0.05.

5 Comparison between concentration index CI results in Algeria and other countries

The results the daily rainfall concentrations values CI in Algeria and in other countries, such as mainland Spain (Martin-Vide, 2004) and Iran (Alijani et al. 2008), China (Zhang et al. 2009) show that the concentration index CI values obtained in all Algerian territory are respectively similar to those found in Peninsular Spain and Iran and they are lower than those found in China.

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Indeed, the concentration index CI of series of precipitation varies between 0.57 and 0.70 respectively for Algeria (an average of 0.63 for the period from 1970 to 2008), between 0.55 and 0.70 for Peninsular Spain (an average of 0.61 for the period from 1951 to 1990), between 0.58 and 0.73 for Iran (an average of 0.64 for the period from 1961 to 1990) and between 0.74 and 0.80 for China (for the period from 1960 to 2005). It was observed that the concentration index (CI) values of Peninsular Spain and Algeria are similar, but not have the same interpretation. For example, the concentration index value in Biskra (CI = 0.70) is explained by the lack of rainfall in this part of the country (125 mm $year^{-1}$), against CI = 0.70 for Valencia (Martin-Vide, 2004) is relatively large amount of precipitation (472 mm $year^{-1}$). This shows that the CI value is closely linked with the intensity and not with the amount of rainfall. The concentration index CI values in Algeria are less than those calculated by Zhang et al. (2009) in China; this might be due to different climatic systems existing in these two countries. In fact, Algeria is dominated by two types of training climate: Mediterranean and Saharan Africa. The Saharan climate locally generated covers most of the surface of Algeria, which is characterized by large seasonal and daily variations of temperature and low and irregular rainfall in some regions of the extreme southeastern region (Illizi, Bbm and Adrar), quantities lower than 20 mm were recorded with high evaporation rates that leave the land arid. On the other hand, "The Pear River Basin" in China is characterized by a climate of current temporal and spatial distribution with highly irregular rainfall. In addition, the amounts of precipitation in "The Pear River Basin" are usually the result of precipitation due to torment and convection. This can cause increases in the concentration index values in comparison with those of Algeria.

6 Conclusion

The daily rainfall concentration in the region of Biskra and in the southwestern part of the country is high, with concentration index values close to 0.70. This reflects the fact that very few rainy days are bringing high percentage of annual precipitation.

The occurrence or not of such large quantities every day can change the character (dry or wet) of any month, season or year. This leads to considerable uncertainty in the average rainfall contributions, which in turn leads to environmental and social impacts.

Thus, it was concluded that in Algeria, the essential features of climate in different regions are characterized by narrow climatic zones close to the coast, under the combined influence of the sea. The relief of the soil, the latitude and the diversity of climates in Algeria lead to a very different rainfall distribution.

The CI values obtained at 42 meteorological stations across Algeria range from 0.70 (Biskra) to 0.57 (M'sila). Tracing isohyets are also largely determined by the topography of the ground. Northern, western and central regions are areas where rainfall is regular compared to Eastern regions while the Southern region shows the most aggressive rainfall.

Supplementary material related to this article is available online at http://www.nat-hazards-earth-syst-sci-discuss.net/2/2709/2014/nhessd-2-2709-2014-supplement.pdf.

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Table 1. Frequency distribution in classes of 1 mm, relative cumulative frequencies X and corresponding percentages of the total precipitation Y in Chlef (1970–2008).

Upper limit	Midpoint	Ni	Σ Ni	Pi	Σ Pi	Σ Ni (%) = X	Σ Pi (%) = Y
0.9	0.5	819	819	409.5	409.5	29.75	2.93
1.9	1.5qq	407	1226	610.5	1020.0	44.53	7.31
2.9	2.5	298	1524	745.0	1765.0	55.36	12.64
3.9	3.5	202	1726	707.0	2472.0	62.70	17.71
4.9	4.5	159	1885	715.5	3187.5	68.47	22.84
5.9	5.5	123	2008	676.5	3864.0	72.94	27.68
6.9	6.5	97	2105	630.5	4494.5	76.46	32.20
7.9	7.5	88	2193	660.0	5154.5	79.66	36.93
8.9	8.5	71	2264	603.5	5758.0	82.24	41.25
9.9	9.5	56	2320	532.0	6290.0	84.27	45.06
10.9	10.5	57	2377	598.5	6888.5	86.34	49.35
11.9	11.5	45	2422	517.5	7406.0	87.98	53.06
12.9	12.5	47	2469	587.5	7993.5	89.68	57.27
13.9	13.5	28	2497	378.0	8371.5	90.70	59.97
14.9	14.5	40	2537	580.0	8951.5	92.15	64.13
15.9	15.5	27	2564	418.5	9370.0	93.13	67.13
16.9	16.5	27	2591	445.5	9815.5	94.12	70.32
17.9	17.5	19	2610	332.5	10 148.0	94.81	72.70
18.9	18.5	19	2629	351.5	10 499.5	95.50	75.22
19.9	19.5	20	2649	390.0	10 889.5	96.22	78.01
20.9	20.5	12	2661	246.0	11 135.5	96.66	79.78
21.9	21.5	11	2672	236.5	11 372.0	97.06	81.47
22.9	22.5	13	2685	292.5	11 664.5	97.53	83.57
23.9	23.5	10	2695	235.0	11 899.5	97.89	85.25
24.9	24.5	9	2704	220.5	12 120.0	98.22	86.83
25.9	25.5	3	2707	76.5	12 196.5	98.33	87.38
26.9	26.5	3	2710	79.5	12 276.0	98.44	87.95
27.9	27.5	3	2713	82.5	12 358.5	98.55	88.54
28.9	28.5	3	2716	85.5	12 444.0	98.66	89.15
29.9	29.5	5	2721	147.5	12 591.5	98.84	90.21
30.9	30.5	2	2723	61.0	12 652.5	98.91	90.64
31.9	31.5	1	2724	31.5	12 684.0	98.95	90.87
33.9	33.5	4	2728	134.0	12 818.0	99.09	91.83
34.9	34.5	2	2730	69.0	12 887.0	99.16	92.32
36.9	36.5	4	2734	146.0	13 033.0	99.31	93.37
37.9	37.5	1	2735	37.5	13 070.5	99.35	93.64
38.9	38.5	1	2736	38.5	13 109.0	99.38	93.91
39.9	39.5	1	2737	39.5	13 148.5	99.42	94.20
40.9	40.5	1	2738	40.5	13 189.0	99.46	94.49
41.9	41.5	2	2740	83.0	13 272.0	99.53	95.08
42.9	42.5	3	2743	127.5	13 399.5	99.64	96.00
43.9	43.5	1	2744	43.5	13 443.0	99.67	96.31
44.9	44.5	3	2747	133.5	13 576.5	99.78	97.26
45.9	45.5	1	2748	45.5	13 622.0	99.82	97.59
53.9	53.5	1	2749	53.5	13 675.5	99.85	97.97
57.9	57.5	1	2750	57.5	13 733.0	99.89	98.38
62.9	62.5	1	2751	62.5	13 795.5	99.93	98.83
63.9	63.5	1	2752	63.5	13 859.0	99.96	99.29
100.9	99.5	1	2753	99.5	13 958.5	100.00	100.00
Sum		2753		13 958.5		4448.27	3565.80

Table 2. Geographic coordinates and average annual rainfall (P), Variation Coefficient (VC) and average number of rainy days (N) for 42 meteorological stations across Algeria (period from 1970 to 2008).

Station (code map)	Latitude	Longitude	Altitude (m)	Study period	P (mm)	VC (%)	N
Adrar (AD)	27°49′	−0°11′	279	1970–2008	18	99	11
Ain Sefra (AS)	32°46′	−0°36′	1058	1977–2008	166	57	50
Annaba (AN)	36°50′	7°48′	3	1970–2008	651	23	120
Batna A. Skhouna (BA)	35°45′	6°19′	827	1972–2008	322	36	97
Béchar (BC)	31°30′	−2°15′	807	1970–2008	91	56	36
Béjaia Aéro (BJ)	36°43′	5°04′	2	1970–2008	770	46	109
Béni Abbès (BN)	30°08′	−2°10′	499	1970–2008	36	76	22
Biskra (BK)	34°48′	5°44′	82	1970–2008	125	46	42
Bordj B. Arreridj (BB)	36°04′	4°46′	928	1981–2008	337	37	87
Chlef (CH)	36°12′	1°20′	143	1970–2008	361	27	77
Constantine (CO)	36°17′	6°37′	694	1970–2008	523	28	114
Dar El Beida (DB)	36°41′	3°13′	25	1970–2008	643	30	112
Djelfa (DJ)	34°20′	3°23′	1180	1971–2008	311	33	90
El Bayadh (EB)	33°40′	−1°00′	1341	1971–2008	256	39	85
El Golea (EG)	30°34′	2°52′	397	1970–2008	36	75	17
El Kheiter (EK)	34°09′	0°04′	1000	1978–2008	204	39	68
El Oued Guemar (OG)	33°30′	6°47′	64	1970–2008	73	53	34
Ghardaia (GH)	32°24′	3°48′	468	1970–2008	74	51	31
Hassi Messaoud (HM)	31°40′	6°09′	142	1970–2008	38	66	19
In Amenas (IA)	28°03′	9°38′	561	1970–2008	26	97	15
In Salah (IS)	27°14′	2°30′	268	1970–2008	16	97	16
M'sila (MI)	35°40′	4°30′	441	1977–2008	181	39	43
Maghnia (MG)	34°49′	−1°47′	427	1976–2008	288	27	64
Mascara Matmore (MS)	35°36′	0°18′	474	1977–2008	320	31	72
Miliana (ML)	36°18′	2°14′	715	1971–2008	746	28	109
Mostaganem Ville (MO)	35°53′	0°07′	137	1976–2008	357	30	65
Oran Sénia(OR)	35°38′	−0°36′	90	1970–2008	352	27	82
Saida (SD)	34°52′	0°09′	750	1977–2008	323	32	76
Setif Ain Sfiha (ST)	36°11′	5°15′	1033	1981–2008	404	23	97
Skikda Port(SK)	36°53′	6°54′	1	1970–2008	725	22	108
Tamanrasset Aéro (TA)	22°48′	5°26′	1362	1970–2008	49	76	26
Tébessa (TB)	35°25′	8°07′	820	1972–2008	346	38	90
Tiaret (TI)	35°21′	1°28′	977	1983–2008	335	27	89
Timimoun (TM)	29°15′	0°17′	312	1970–2008	21	93	11
Tindouf (TN)	27°42′	−8°10′	443	1970–2008	34	84	15
Tlemcen Zenata (TL)	35°01′	−1°28′	210	1980–2008	310	27	65
Touggourt (TG)	33°04′	6°05′	85	1974–2008	65	59	19
BBM (BM)	21°20′	0°57′	397	1993–2008	20	58	5
Illizi (IL)	26°30′	8°26′	543	1992–2008	11	74	4
Ouargla (Ou)	31°56′	5°24′	144	1990–2008	21	78	10
In Guezzam (IG)	19°34′	5°46′	400	1994–2008	25	95	5
Asskrem (AK)	23°16′	5°38′	2710	1980–2008	132	60	35

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Table 3. Values of constants *a* and *b* of the exponential curves given by Eq. (1). The concentration index CI and the rainfall percentage contributed by 25 % of rainy days for 42 weather stations across Algeria (period from 1970 to 2008).

Station (code map)	a	b	CI	Rainfall (%)
Adrar (AD)	0.023	0.036	0.66	76.2
Ain Sefra (AS)	0.021	0.037	0.65	75.9
Annaba (AN)	0.034	0.033	0.59	70.2
Batna A.Skhouna (BA)	0.031	0.034	0.61	73.0
Béchar (BC)	0.019	0.038	0.66	76.0
Béjaia Aéro (BJ)	0.024	0.036	0.63	73.0
Béni Abbès (BN)	0.022	0.036	0.66	76.1
Biskra (BK)	0.017	0.040	0.70	77.1
Bordj B.Arreridj (BB)	0.030	0.034	0.62	73.0
Chlef (CH)	0.036	0.033	0.59	70.2
Constantine (CO)	0.028	0.035	0.62	72.5
Dar El Beida (DB)	0.025	0.036	0.62	72.9
Djelfa (DJ)	0.043	0.031	0.58	70.5
El Bayadh (EB)	0.036	0.032	0.60	72.0
El Golea (EG)	0.027	0.035	0.64	74.8
El Kheiter (EK)	0.029	0.034	0.62	72.5
El Oued Guemar (OG)	0.025	0.036	0.64	74.9
Ghardaïa (GH)	0.025	0.036	0.64	75.3
Hassi Messaoud (HM)	0.039	0.031	0.62	73.5
In Amenas (IA)	0.026	0.035	0.64	75.0
In Salah (IS)	0.023	0.037	0.63	74.9
M'sila (MI)	0.058	0.028	0.57	66.0
Maghnia (MG)	0.036	0.032	0.60	70.9
Mascara Matmore (MS)	0.036	0.032	0.60	71.0
Miliana (ML)	0.020	0.038	0.65	7.0
Mostaganem Ville (MO)	0.024	0.036	0.64	74.0
Oran Sénia (OR)	0.026	0.036	0.63	74.0
Saida (SD)	0.035	0.033	0.60	71.0
Setif Ain Sfiha (ST)	0.029	0.035	0.61	72.0
Skikda Port(SK)	0.033	0.033	0.60	71.0
Tamanrasset Aéro (TA)	0.020	0.037	0.67	77.0
Tébessa (TB)	0.028	0.035	0.62	72.5
Tiaret (TI)	0.045	0.030	0.58	69.0
Timimoun (TM)	0.057	0.026	0.61	71.8
Tindouf (TN)	0.021	0.036	0.69	79.0
Tlemcen Zenata (TL)	0.027	0.035	0.62	73.0
Touggourt (TG)	0.029	0.034	0.63	72.5
BBM (BM)	0.024	0.036	0.65	76.0
Illizi (IL)	0.029	0.033	0.66	77.5
Ouargla (Ou)	0.028	0.035	0.62	74.0
In Guezzam (IG)	0.053	0.026	0.65	73.5
Asskrem (AK)	0.017	0.039	0.68	78.8

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Table 4. Values of Pearson's correlation coefficient, Spearman's rho and Kendall's tau-b for pairs of variables: (CI, *P*); (CI, CV) and (CI, *N*).

Type of Correlation	Pearson's correlation coefficient	Spearman's rho	Kendall's tau-b
Between CI and *P*	−0.43	−0.50	−0.32
Between CI and VC	0.54	0.61	0.44
Between CI and *N*	−0.53	−0.54	−0.37
Significance levels	0.01; 0.05		
Decision of test	The correlation is significant at Alpha = 0.01 and Alpha = 0.05		

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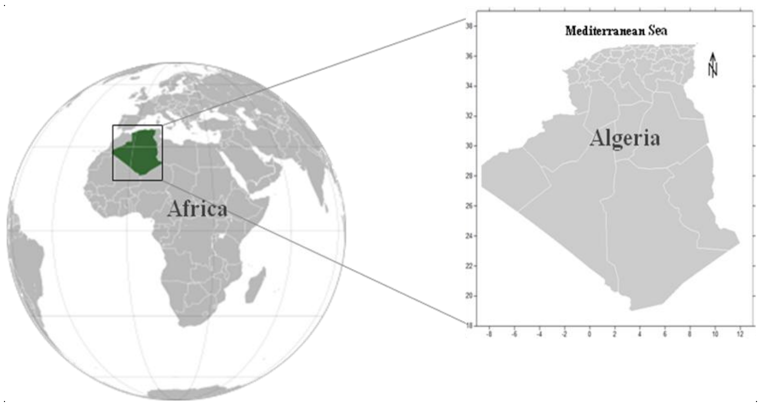

Fig. 1. Geographical location of the study area (Algeria).

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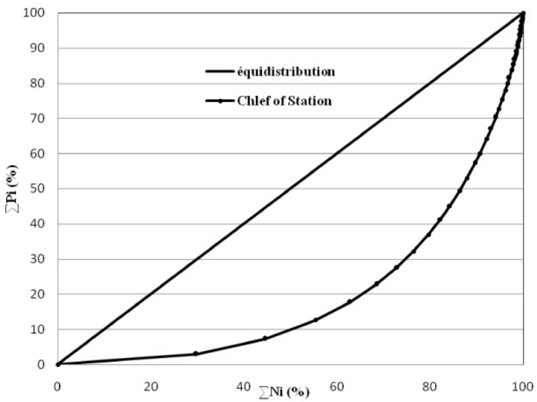

Fig. 2. Concentration or Lorenz curves of Chlef meteorological station (1970–2008).

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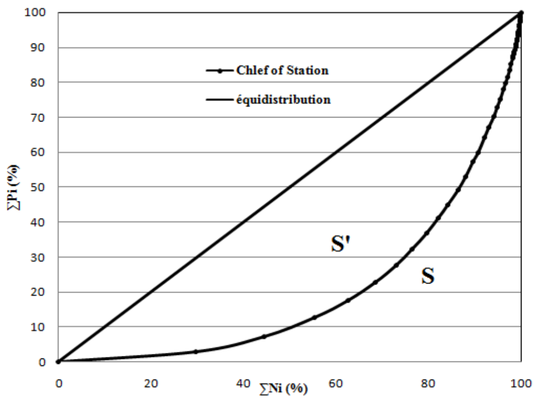

Fig. 3. Concentration curve adjusted from the exponential curve of the Chlef meteorological station (1970–2008).

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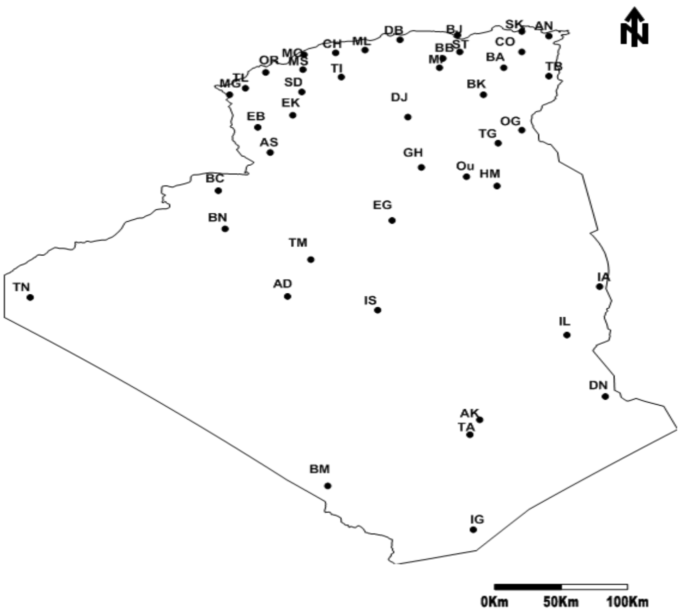

Fig. 4. Location of meteorological stations analyzed.

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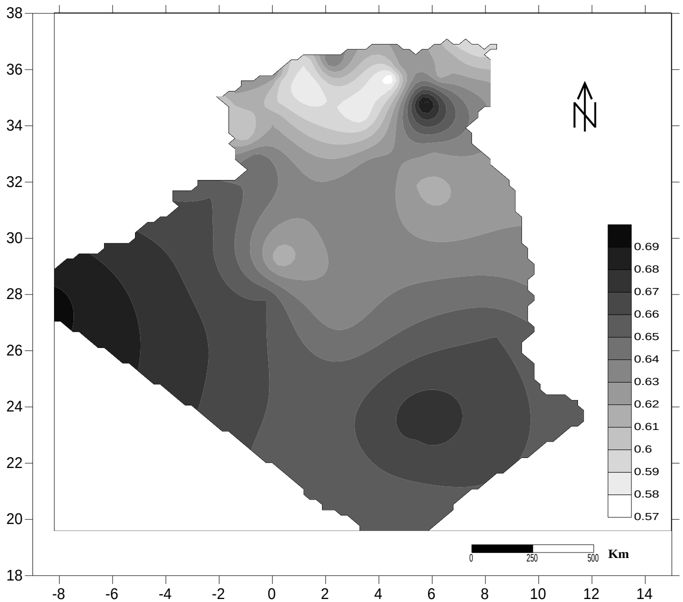

Fig. 5. Spatial distribution of CI values in Algeria.

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