STUDY OF THE INTERANNUAL RAINFALL VARIABILITY IN NORTHERN ALGERIA

ETUDE DE LA VARIABILITE INTER-ANNUELLE DES PLUIES DE L'ALGERIE SEPTENTRIONALE

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ABSTRACT : The work presented here focuses on the inter-annual variability of annual rainfall in Northern Algeria. This work is carried out by using the coefficient of variation (the ratio between the standard deviation and the average). We will try to show areas of low, medium and high variations in Northern Algeria. In order to do this, we use 333 rainfall stations spread over the entire study area, with a measurement period of 37 years (1968/2004). The contrast of rainfall spatial and temporal distribution has been demonstrated by studying the sixteen basins, as adopted by the National Agency of Water Resources. The high spatial variability characterizes the basins of the High Plateaus of Constantine and Chot El Hodna.

Keywords: Northern Algeria - annual Rainfall - inter-annual variability - coefficient of variation

RESUME : Nous présentons dans cet article une étude de la variabilité interannuelle des pluies annuelles en Algérie septentrionale. Ce travail a été réalisé en utilisant le coefficient de variation (le rapport entre l'écart-type et la moyenne). Nous essayerons de montrer les zones à faible, moyenne et forte variations dans le Nord de l'Algérie. Pour se faire, nous avons utilisé 333 postes pluviométriques réparties sur l'ensemble de la zone d'étude avec une période de mesure de 37 ans (1968/2004). Le contraste des répartition spatiale et temporelle des pluies a été mis en évidence en étudiant les seize bassins hydrographiques tel qu'adopté par l'Agence Nationale des Ressources Hydrauliques. La forte variabilité spatiale caractérise les bassins des Hauts plateaux Constantinois et Chott El Hodna.

Mots Clés : Algérie septentrionale - Pluies annuelles - variabilité interannuelle - coefficient de variation

INTRODUCTION

In this work, we will try to study the interannual variability of annual rainfall in Northern Algeria through the coefficient of variation, and then we will prepare a cartographic sketch of these coefficients. This coefficient is very effective to present the relative dispersion of the average annual rainfall around the global average. The coefficient of variation proves to be the most satisfactory of all the dispersion measurement parameters used in the comparative study of rainfall variability in several stations (Grisollet in Mebarki, 1982). The purpose of this work is to show areas of low and high rainfall variability in view of installing new stations to refine the study of rainfall spatial variation at different scales (essential for basin development studies, agriculture….). The study area is characterized by rugged topography, which creates a strong spatial variation in rainfall (Chaumont, 1972; Laborde, 1998; Meddi and Hubert, 2003; Meddi et al., 2009)..

The study of the inter-annual variability of rainfall is very important to understand the climatic trend and forecast. A consistent study requires a large number of measuring stations, compared to the size of the study area, and long observation series in order to make the study representative of climate change. In our case, the fulfillment of these two conditions was very difficult (incomplete observation series at several rainfall stations). To consider the maximum measurement points, we took a period of 37 year (1968/1969 - 2003/2004). The number of rainfall stations is 333.

MEASUREMENT NETWORK

Northern Algeria consists of 16 large basins according to the division of the National Agency of Water Resources

Table 1 shows the basins and number of stations per basin. The density of rainfall stations is very low compared to the W.M.O recommendations. The basins of Chott Melrhir (06) and the high plateaus of Oran (08) each have a station for 2644 km^2 and 3291 km^2 respectively. The two basins that are relatively well represented are the Isser basin (09) (a station for 277 km^2) and the Seybouse basin (a station for 308 km^2). Most of the measurement network was stopped during the period from 1954 to 1962; other stations have changed their locations or names after 1962 (for example: before 1962, the station of Ain Larbi was known as Gounod (Ghachi, 1986), which gives, in the observation directories, rainfall series under different names and creates series that contain errors. A large number of rainfall stations was installed from 1968, as part of restructuring the network of rainfall stations. The number of stations used in the study, and the reference period are affected by these constraints. During this period and at selected stations, gaps are minimal compared to the entire observation period and all stations. The critical review of data results in considering 314 rainfall stations and a period of 37-years (1968/1969 to 2003/2004). This period is considered homogeneous (recent measurements made by qualified technicians, saving the station's names and not moving the measuring stations). The representativeness of the reference period (37 years) cannot be sufficient to give a true picture of precipitation because of the significant rainfall deficit recorded over the last 17 years, particularly in the western region of Algeria. But as our study focuses only on inter-annual variations, we can estimate that this period can be considered representative and allows a cartographic representation of rainfall variations from one year to another.

PRESENTATION OF THE STUDY AREA

The study area covers approximately 381 000 km^2, of which 200 000 km^2 consist of plains and plateaus. It is located between 9° East and approximately 3° West (Figure 1).

The coastline covers approximately 1200 km. it is characterized by a mild climate, humidity is relatively high and rainfall varies from 400 mm in the West to 1000 mm in the East.

The Tell Atlas begins in the West by the heights of Mount Tessala (1061m), located on the northern border of the Sidi Bel Abbes Plain, followed by the mountains of : Daya (1417 m), Saida (1288m), Frenda (1132 m), El Ouencheriss (1985 m), Dahra (1071 m) and Zekkar (1579 m). A series of mountains formed by the Mitidja Atlas (1972 m) begins east of Mount Zekkar, the heights of Kabylie (Djurdjura 2328 m) are east of it. The Tell Atlas is also made up of coastal plains (the plains of Oran, Mitidja and Annaba) and inland plains (the plains of Tlemcen, Sidi Bel Abbess and Sersou). The high plateaus cover about 700 km, they extend from West to East, the heights vary from 1000 to 1200 m (Tlemcen mount, 1142 m).

The high plateaus get narrower in the East because of their proximity to the Tell Atlas: altitude decreases to 400 m at Chott El Hodna. These high altitudes represent natural barriers to the clouds that produce rain. Several authors have shown that much of the rainfall variance is explained by altitude and landform (Laborde, 1982); Colibaly, 1989; Humbert and Paul, 1982; Meddi, 1992 and Bouzina & al., 1994).

The Saharan Atlas is considered as a natural boundary between the North and South over a distance of about 700 km. It consists of a discontinuous series of mountains. In the west, we have the mountains of: Ksour (1980 m), Amour (1683 m) and Ouled Nail (1500 m) and in the east we have Mount El Aures (2328 m). Northern Algeria consists of 16 large basins according to the division of the National Agency of Water Resources (Table 1 and Figures 1 and 2).

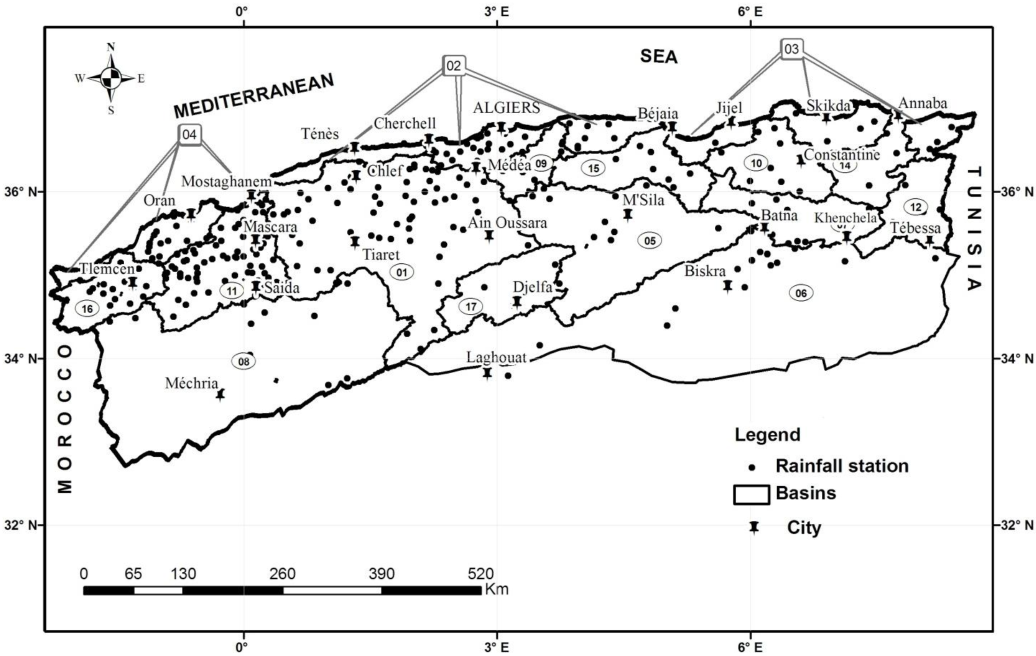

Fig. 1. Rainfall stations and basins according to the division of the National Agency of Water Resources.

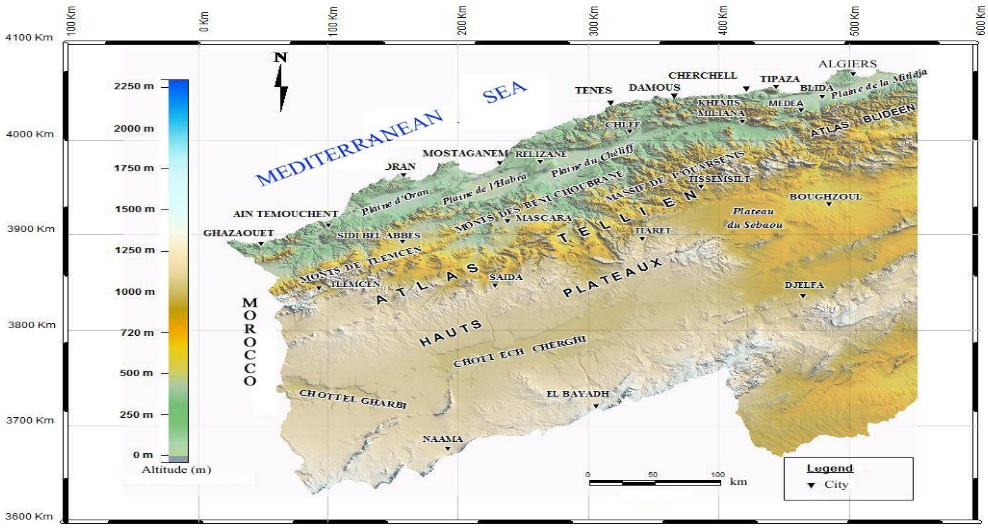

Fig. 2 Topography of the studied area

Table 1. Major basins in Northern Algeria.

Basin	Basin	Area Km^2	Number of rainfall stations	Minimum altitude m	Maximum altitude m
01	Cheliff	43750	70	20	1983
02	Côtiers Algérois	11972	37	10	2305
03	Côtiers Constantinois	11566	13	25	1220
04	Côtiers Oranais	5831	21	65	1113
05	Chott El Hodna	25843	14	435	1862
06	Chott Melrhir	68750	25	190	2326
07	H. Plateaux Constantinois	9578	8	890	2300
08	H. Plateaux Oranais	49370	10	720	1650
09	Isser	4149	7	90	1810
10	Kebir Rhumel	8815	10	15	1729
11	Macta	14389	68	600	1238
12	Medjerdah	7785	6	480	1626
14	Seybousse	6475	6	10	1635
15	Soummam	9125	17	210	2305
16	Tafna	7245	15	50	1824
17	Zahrez	9102	05	850	1350
	Total	**293745**	**333**		

CLIMATE AND RAINFALL

Precipitations

The Northern part is characterized by a Mediterranean climate with one relatively cold and rainy winter and hot and dry summer. North East of Algeria is subjected to very irregular space-time rainfall variations. A precipitation reaches 400 mm in the West, 700 mm in the Center and 1000 mm in the East Part of the coast (figure 3).This type of climate also relates to the mountain chains of the Tellian Atlas; where one records on several Eastern tops, rainfall amount varying from 800 to 1600 mm, whereas the values drop towards the Center (700 to 1000 mm) and towards the West (600 mm).On the level of the plains at the toe of the Tellian Atlas, precipitations varie from 500 mm in the West, 450 mm in the center and of 700 mm in the East. The Saharian Atlas is characterized by a very hot and dryness climate in summer, soft in winter with less rainfall compared to the North because of its distance from the sea. Djurdjura mountain chains situated in the region of kabylie, and the Edough mountain chains situated more towards the Est, are the zones of most important rainfall of the whole

Algeria, where the precipitation exceeds 1200mm per year. Rainfall characteristics are shown in Table 2

Table 2. Annual rainfall characteristics and coefficients of variation of rainfall series recorded at each basin

Bassins	Mean annual rainfall (mm)		Coefficient of Variation		Bassins	Mean annual rainfall (mm)		Coefficient of Variation	
	Min value	Max value	Min value	Max value		Min value	Max value	Min value	Max value
Cheliff	148.4	745.9	0.17	0.45	**Isser**	368.4	812.3	0.18	0.38
Côtiers Algérois	531.7	948.8	0.17	0.42	**Kebir Rhumel**	254.2	1337.5	0.13	0.54
Côtiers Constantinois	547.6	1045.1	0.18	0.35	**Macta**	206.0	380.9	0.22	0.44
Côtiers Oranais	302.5	397.7	0.29	0.42	**Medjerdah**	279.7	1011.6	0.22	0.42
Chott El Hodna	113.2	350.4	0.24	0.78	**Seybouse**	225.9	767.4	0.24	0.48
Chott Melrhir	93.0	404.9	0.30	0.48	**Soummam**	310.8	574.7	0.21	0.48
H. Plateaux Constantinois	179.5	501.6	0.19	0.58	**Tafna**	263.0	656.7	0.27	0.50
H. Plateaux Oranais	136.3	295.1	0.20	0.46					

Coefficient of variation

To characterize spatial and temporal variability, we use the coefficient of variation expressed as a percentage (%). The coefficient of variation often characterizes the variability of rainfall (Chadule groupe, 1994). It is the ratio of the standard deviation of a series to the mean (Cam Berlin et al., 1994).

$$CV = \left(\sigma / \bar{x}\right) \times 100 \qquad (1)$$

$\bar{x}$: Mean of the series;

σ : Standard deviation.

We recall that according to Matthews (1981), the coefficient of variation is an effective measure of the variability in comparison with the mean of a sample, and its values are generally higher if the mean of the series are small. This coefficient was used by Naheed et al.(2010) in Pakistan, Mul et al. (2009) in Tanzania, Mugabe et al. (2007) in Zimbabwe, Zhao et al. (2011) in Australia, Mohapatra et al. (2006) in India, Desa et al. (1996) in Malaysia, Rodriguez-Puebla et al. (1998) in Spain.

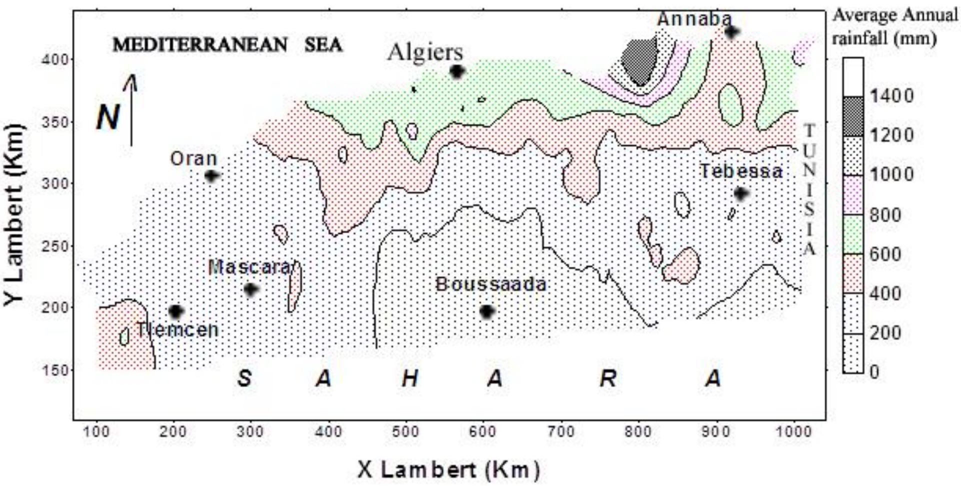

Fig. 3. Annual Rainfall (Meddi, 1995)

Mapping

Mapping allows us to assess the spatial variability of the results coming from descriptive statistics (Berthelot, 2008). For a better spatial representation of rainfall variability, interpolation is the best technical tool. It allows estimating the value of a variable at a given point, using the values of the study variable measured at neighboring sites. This approach allows a more accurate estimation than that of the spotlight mapping.

Two approaches are widely used for spatial rainfall estimation:

- Geostatistical approach (kriging), after identifying the spatial structure from the values measured at rainfall stations (Hevesi et al., 1992).
- The approach based on statistical relationships between precipitation and terrain features.

Geostatistics is widely used in natural and earth sciences such as: meteorology, civil engineering, environment, oceanography, geology, water and soil quality. Unlike conventional interpolation techniques, geostatistics uses a linear combination of measured data and also takes into account the geographical position of the point under consideration and the random nature of the phenomenon.

We opted for the first approach to represent the spatial variability of the coefficient of variation. Kriging is widely used for the interpolation of a regionalized variable by introducing the technique of experimental variogram. The latter is essential before starting the implementation of kriging. The variogram is a tool for the structural analysis of the regionalized variable in order to describe the spatial structure of this variable (Serra, 1967; Meylan, 1986). The kriging is the optimal method, in a statistical sense, of interpolation and extrapolation. It is the most accurate estimation method. Unlike all the other methods, it also allows us to calculate the estimation error. There are three types of kriging (simple kriging, ordinary kriging and universal kriging). The difference between these three types of estimates lies in the knowledge of the statistics of the variable to be interpolated:

(1) Simple kriging: stationary variable of known mean.
(2) Ordinary kriging: stationary variable of unknown mean.
(3) Universal kriging: non-stationary variable (which contains a trend).

Mapping coefficients of variations

To map the spatial variability of the coefficients of variation of average annual rainfall in Northern Algeria, we used information from 333 sites (rainfall stations). These stations enabled us first of all to establish the variogram that must precede the kriging; it is exponential. This variogram was used to perform an ordinary kriging (probabilistic approach of prediction) of the variable « Coefficient of Variation » on a mesh of 1,33 km.

The study of residuals (difference between the actual values at 302 sites and the values resulting from the interpolation used in plotting) provides:

- 51 % of sites have an error of less than 10%.
- 79 % of sites have an error of less than 20%.
- 97 % of sites have an error of less than 30%.

The root-mean-square error or standard error of prediction quantifies the uncertainty of the prediction. It is equal to the square-root of the prediction variance, variation associated to the difference between the actual and predicted value. We note that the error is minimal for the ordinary kriging (Tab. 3). So, it has been used to map the spatial variation of the coefficients of variations. This type of kriging is widely used in the world (Berthelot, 2008; Meteo-France, 2011; Renard et al., 2009; Guerra et al., 2006; Renard, 2007)

Table 3. Estimation error for the three types of kriging

	Average Standard Error
Simple Kriging	0,07344
Ordinary kriging	0,04786
Universal kriging	0,05049

CALCULATION OF THE FINAL MAP

The estimation of the coefficients of variation at the mesh points of the study area is made by the sum of two layers: the first is derived from the kriging of the CV values measured at rainfall stations, and the second layers represents residuals (the unexplained part of the coefficients of variations) and enables the optimization of the final result (Meddi 1992; Laborde, 1998 and 1997; Dumas, 1998; Mebarki 2008).

Some researchers focuses especially on residuals which reflect the true spatial roughness variables, while models show only the major smoothed trends of the phenomenon (Dumas, 1998). The imporatnce of considering residuals in the final results of spatial distribution has been shown by many authors: Laborde, 1984 in Northeastern France; Meddi, 1992 in the Wadi Mina basin in Algeria, Humbert, 1993 and 1997 in the Vosges Mountains in France. These residuals correspond to a portion of the coefficients of variations that are not explained directly by ordinary kriging (Dumas, 1998). To add these residuals to the calculated coefficeients of variation, we have regionalized the residuals with interpolation using kriging algorithm according to the experimental variogram (Figure 4 and 5). In this way, we obtain for each point a value of residuals that allow correcting the calculated variation coefficients and optimizing the final result for the entire study area.

The addition of interpolated residuals to the values of the calculated coffecients of variations allow us to obtain the final coefficients of variations to be mapped (Figure 6).

The study of the new grid's residuals gives the following results, where we notice that the order of error has significantly decreased and estimations have became more acceptable for the final map of two layers (one of residual and the second of the initials variation coefficient):

- 89 % of points have an error of less than 5 %.

- 96 % of points have an error of less than 10 %.
- 99, 3 % of points have an error of less than 20 %.

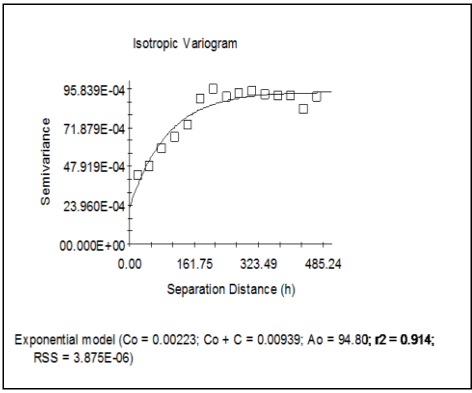

Fig. 4. Experimental variogram of residuals

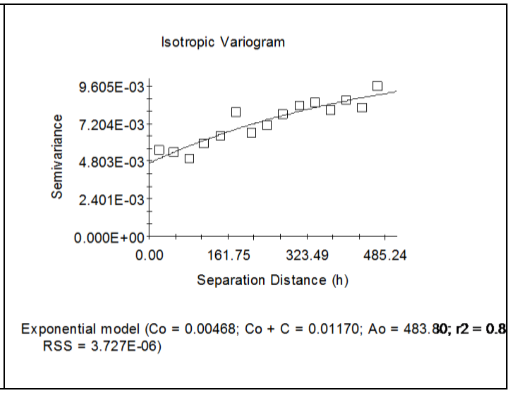

Fig. 5. Experimental variogram of initial values of Cv

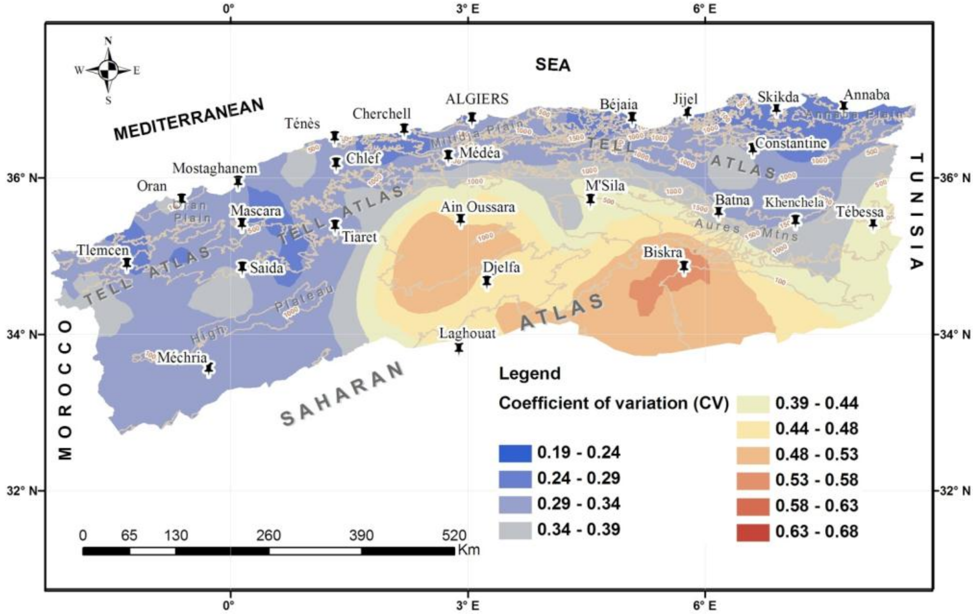

Fig. 6. Map of the spatial variation of the coefficients of variation in Northern Algeria

COMMENTS

The Chellif basin (01)

The Chellif basin is characterized by an average annual rainfall ranging from 148 mm to 746 mm from one station to another. The coefficient of variation of annual averages is around 30 %, which shows a moderate variability.

At the annual scale, the spatial variability (between stations) is high (51 %). It is accentuated by:

-Stormy autumn and summer rain caused by northwest winds (Meddi M. 1992), affecting the northwestern and southwestern parts of the basin,

-Heavy winter and spring rain, received by the mountainous parts (Dahra mount, 1604 m, El Ouancheriss mount, 1710 to 1786 m, and the Tiaret mountains where the altitude exceeds 1200 m), compared with the Chellif valley and the Oued Mina Basin.

The inter-annual variability for the stations of this basin varies from 17% to 45%. Stations in the oriental part of the basin have a higher coefficient of variation than that of the West and stations located in summits (Fig 3).

The coastal Algiers basin (02)

The coastal Algiers basin (02) is characterized by a very rugged terrain with summits that reach 1415 m (Dahra mount) in the western part of the basin and 2308 m (Djurdjura mount) in the eastern part of the basin. These mountain ranges, in addition to the Blidean Atlas, cause the progressive depletion of atmospheric water vapor. These mountain ranges have great influence on rainfall spatial variation (Aissani, 1983; Halimi, 1980). Average annual rainfall varies from532 mm to 950 mm. This variability is caused by the effect of altitude, distance from the sea and landform (wind exposure), Laborde (1998) and Meddi et al. (2009). The prevailing humid winds are from north, northeast and northwest, depending on the season. Thus, the stations that have exposures in these directions receive the heaviest rain (for example: at the Chrea station (1550 m) recorded 940 mm on average while the station of Blida (267 m) records 660 mm an average rainfall.

The spatial variability of rainfall, from one station to another, varies from 18 % to 47%. 70 % of stations have a coefficient of variation relatively close to the average (25%) and 30% of stations have a coefficient greater than 30%.

The coastal Constantine basin (03)

The coastal Constantine basin is characterized by rugged terrain. Elevations can reach 1833 m (Babour mount). Average annual rainfall varies from 548 mm in the region of Guelma (200 m) to 1045 mm in the region of Jijel and El Kala in the Extreme East. This basin is characterized by a low spatial variation of average annual rainfall (20%) compared to other basins. The heavy rains that characterize this basin reduce the spatial variability of rainfall.

The coastal Oran basin (04)

The coastal Oran basin has less rugged topography. Elevation in The plain of Oran hardly exceeds 100 m. It is also characterized by low rainfall (from 302 mm at the station of Marsa Ben Mhidi in the Extreme West to 398 mm at Hammam Bouhadjar). These low percentages are mainly due to moderate topography and low rainfall recorded in the basin in recent decades (Meddi et al., 2009). These decades are characterized by a change in rainfall regime that hit the Maghreb countries and the Mediterranean basin : Kingumbi et al. (2000) in Tunisia; Sebbar et al., (2011) in Morocco; Yesilırmak et al. (2008) in Turkey; Costa et al. (2009) in Portugal; Caloiero et al. (2009) in Italy); Meddi et al. (2003) in the West of Algeria. It caused a reduction in rainfall of about 20% in this basin (Meddi et al., 2003, Meddi et al., 2002).

The Hodna basin (05)

The Hodna basin is bounded on the north by El Hodna mounts and the Tetri summits (1810 m). Rainfall is very low (from 113 mm to 350 mm). These low values are due to the mountainous barrier formed by El Hodna and Tetri mounts that prevent the progression of moisture-bearing winds, and the distance between the basin and the sea. Spatial variation between stations is about 45%. In Algeria, the rainfall decreases from North to South and from East to West (Chaumont, 1972; Laborde, 1998; Meddi, 1992; Meddi, 2009; Meddi et al., 2012). The heavy rains in this basin are recorded at the Tetri summits and El Hodna mounts (region of Bordj Bouaredj). However, the lowest rains are measured in the southern region of the basin (Bousâada and Ain Rich) and in the part that follows El Biban mounts (between Ain El Hadjal and M'Sila). This difference in rainfall from one region to another increases the spatial variation of rainfall (about 58%).

The Chott Melrhir basin (06)

The Chott Melrhir basin covers an area of 68750 km^2, from 2° East to 8° East at the Algerian-Tunisian border. It is characterized by a semi-arid and arid climate. It is bounded on the northeast by Ouress mounts (2326 m), on the northwest by Ouled Nail mounts (1570 m) and Amour mount (2008 m). In its eastern region, there is Nmamcha mount and in particular, El Ank mounts (1338 m).

Annual rainfall is low; it varies from 93 mm in the region of Laghouat to 405 mm in the El Kantra region, south side of Ouress mounts. The spatial variability of rainfall is very significant (57%). This high spatial variation is mainly due to the size of the basin, which generates significant climatic variations. In this basin, the direct impact of topography and geographical location is notable (at both sites, with the same morphometric characteristics and located along the flow of moisture-laden air masses, it will rain on the site subject to winds, and cloud masses can not reach the second site (Laborde, 1998).

The Constantine High Plateaus basin (07)

The **Constantinois** High Plateaus basin includes in the northern and central parts, summits ranging from 500 m to 1200 m, it is bounded on the south by the Ouress mounts (Chilia, 2326 m) and El Blazma (2094 m).

Average annual rainfall is from 180 mm in Boullhilet (985 m) on the northeastern side of the Ouress mounts, to 502 mm in Seguene (1409 m) on the northwestern side of the Ouress mounts, where northerly and north-westerly moist winds unload their rains as a priority. The spatial variation is about 58%. The high variability of annual rainfall increases the spatial variation.

The Oran High Plateaus basin (08)

The Oran high plateaus basin is bounded on the north by the Frenda Mountains, Saida mount (above 1200 m) and Daya mount (1356 m), on the west by the Tlemecen Mountains (1843 m) and on the south by Amour mount (2008 m) and Aissi mount (2236 m).

Annual rainfall is low in this basin; it varies from 136 mm to 295 mm. it is mainly due to the distance from the sea and the role of the mountainous barrier in the north of the basin. The spatial variation is about 34%. This moderate variation is mainly due to the topography of the basin and low rainfall in this basin.

The Issers basin (09)

The Issers basin is bounded on the northwest by the Blidean Atlas (1629 m) and the Mitidja Plain, on the northeast by the Djurjura Mountain (2308 m) and on the south by the Titeri (1810 m). Annual rainfall varies from 370 mm in Beni Slimane (600 m) in the southern part of the basin to 812 mm in the region of Lakhdaria (above 1000 m). The spatial variation is moderate (25%). This moderation can be explained by the heavy rains (averages of all stations equal to 607 mm) and the topography that allows to the major part of the basin to be affected by rainy winds.

The Kebir Rhumel basin (10)

The Kebir Rhumel basin lies between the Mediterranean Sea in the north and the High Plains in the south; it has a compartmentalized relief, reflecting the topography of the Tell-High Plains that characterizes it (Mebarki, 2004). The southern part of the basin has elevations above 1200 m and the summits of Guerioun, Tamesguida and Sidi Mimoune exceed 1600 m. The High Plains are between 600 m and 1200 m. Elevations below 600 m correspond to the northern part of the basin (Mebarki, 1984).

Annual rainfall varies from 254 mm in the region of Ain Mlila (elevations from 500 m to 1000 m) to 1338 mm in the northern part of the basin (elevations below 200 m). The spatial variation is very strong (62%). This high variability is caused by the role of the Tell Atlas range (from west to east), that act as a barrier to the arrival of rainy winds, which gives a well-watered part in the north of the basin, and a part of low to medium rainfall in the south. This high spatial variability makes it difficult to choose a representative station for the entire basin.

This shows the need for an average estimation of rainfall, at all-time scales, when studying the dimensioning of hydraulic structures.

The Macta basin (11)

The Macta basin (Western Algeria) is bounded on the north by the Mediterranean Sea, on the south by the Saida Mountains (1201 m) and Daya Mountains (1356 m), and on the southwest by the Tlemcen Mountains, including the Beni Chougranne Mountains and the Mohamadia Plain.

Annual rainfall is low. It varies from 206 mm on the southern part of the Beni Chougranne Mountains (Bouhnifia and Sfisef) to 380 mm on the Saida Mountains and the northwestern part of Sidi Bel abbess and Tessala Mountains. The spatial variation is moderate (25%). This low variability is mainly due to the low rainfall in the region despite the very rugged topography of the basin.

The Medjerdah basin (12)

The Medjerdah basin is located along the Algerian-Tunisian border (with a part in the Tunisian territory). It is composed on the north by the mountain of Souk Ahrass (1406 m). Elevations exceed 500 m in almost the entire basin with summits rising to 1000 m around Tebessa and also between Ain Beida and Meskiana.

Average annual rainfall varies from 280 mm at the Ouenza station (elevations below 500 m) to 1012 mm in the northern part of Souk Ahras Mountains, which are exposed to wet winds blowing from North and Northeast. The basin is characterized by a strong spatial variability (51%). This high variability is mainly due to the heavy rains received by the summits of the Souk Ahrass region, where the winds blowing from North and Northwest upload their rains before they arrive to the southern part of the basin which is characterized by low rainfall (280 mm).

The Seybousse basin (14)

The Seybouse basin (Eastern Algeria) consists of high plains, with elevations that reach 1326 m (Settas mount) and the plain of Annaba in the north of the basin (Ghachi, 1986).

Average annual rainfall varies from 226 m in the semi-arid part of the basin (south of the basin) to more than 1000 mm in the northern part of the basin (Louamri, 2009), affected by the prevailing humid winds blowing from the North (Meddi et al., 1993). The spatial variability is about 40% in this basin.

The Soummam basin (15)

The Soummam basin is bounded on the northwest by the Djurjura Mountains (2308 m), on the northeast by Babour mount (1833 m) and on the south by El Hodna mount. It consists of a very rugged terrain with elevations exceeding 2000 m (El Biban mount in the southeast of the basin). The average annual rainfall varies from 310 mm in the region between Setif and Bordj Bourreridj (elevations varies from 500 to 1000 m) to 580 mm in the region of Kerrata (elevation above 1000 m). The spatial variability (between stations) is about 29%.

The Tafna basin (16)

The Tafna basin is located along the Moroccan-Algerian border (Western Algeria). It is bounded on the northwest by Terara Mounts (1021 m) and on the northeast by Tessala Mounts. It consists of Tlemcen mountains in its Southeastern part (from 1576 m to 1843 m), and in its northern part, there are plateaus that range from 200 to 500 m.

Average annual rainfall varies from 260 mm in the Tlemcen Plain to 650 mm on the Tlemcen Mountains. The spatial variability varies is about 30%.

CONCLUSION

At the end of this work, it seems that rainfall variability in Northern Algeria is very significant and varies considerably from one basin to another. It increases from north to south and from east to west following the increase in rain. This variability is great in the basins characterized by a rugged terrain and high summits such as: Kebir Rhumel and the High Plateaus of Constantine. The basins of low rainfall amounts are also characterized by large variations such as: Chott El Hodna, Chott Melrhir and the High Plateaus of Oran. The study of rainfall variability in Northern Algeria showed the need for the installation of new rainfall stations in the different basins, firstly to meet the requirements of the World Meteorological Office and secondly to have an average rainfall close to reality in the different studies of water projects and forecasts in irrigation planning.

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