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Variability and Climate Change in the Bouregreg watershed (Morocco)

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Abstract

Most hydraulic basins experience water deficits. This situation is likely to deteriorate as a result of climate change and worsening of extreme events, particularly the significant reduction in rainfall and generalized drought. The threat of drought still hangs over the country, as in the periods 1980-1985 and 1990-1995 and 1998-2002, during which almost all the watersheds experienced a water deficit leading to the overexploitation of groundwater.

Since the mid-1970s and early 1980s, Morocco has faced a deterioration in its climatic conditions. Studies of the temporal evolution of the climate indicate a decreasing trend of precipitation. This trend is accompanied by rising temperatures. It is noted at the national level a warming of 0.16 ° C per decade since 1960 in conjunction with a decrease in rainfall amounts. This decline is estimated at 15% from 1971 to 2000 according to Benassi (2001). In addition to the downward trend of rainfall, the Moroccan climate is experiencing a significant increase in drought episodes.

The aim of this work is to describe the meteorological conditions of the study site of the Bouregreg watershed in order to answer the problem dealing with the effect of climatic fluctuations. This study allowed us to establish the climatological characterization and the modeling of climatic projection.

Keywords: Variability, Climate Change, Modeling, Watershed, Morocco.

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1. INTRODUCTION

L'analyse de la dynamique temporelle de la sécheresse agricole indique que le Royaume est passé de 5 années de sécheresse sur 40 de 1940 à 1979 à 6 années sur 16 de 1980 à 1995, puis à 4 années sur 7 entre 1996 et 2002 (Barakat Et Handoufe, 1998). La conséquence spatiale de cette évolution temporelle des conditions climatiques est en parallèle à cette dynamique, il est noté une pression agropastorale importante sur les zones humides, à savoir les régions semi-arides comme le bassin versant du Bouregreg. Ce bassin, au contraire des bassins l'avoisinant, est un espace d'autant plus fragile qu'il reste une zone de culture pluviale et d'élevage extensif.

Le Groupe d'experts intergouvernemental sur l'évolution du climat (GIEC) a estimé en 2001 que la plus grande partie du réchauffement observé au cours des 50 dernières années est due aux gaz à effet de serre d'origine humaine. Selon la même source, la poursuite de ces émissions sans politique sérieuse de réduction augmenterait la température globale de 1,4 à 5,8°C entre 1990 et 2100, et le niveau moyen des mers de 9 cm à 88 cm pendant la même période, et continuerait à augmenter pendant des siècles. Le cycle hydrologique sera intensifié, engendrant davantage de sécheresses dans certaines régions et d'inondations dans d'autres (Houghton, 2004 ; Le Treut et al., 2004).

Through its five reports, the IPCC has always sounded the alarm over global warming and its impact on climate disruption through changes in temperature and precipitation patterns. (IPCC, 1990, 1995, 2001, 2007). The report (IPCC, 2007) forecasts, with a higher degree of confidence, a very probable rise in the frequency of extreme events of temperature, heat waves and episodes of heavy precipitation.

His latest report (IPCC, 2014) states that in recent decades climate change has caused vulnerability and impacts on human and natural systems on all continents and across the oceans. And quotes also that changes in weather extremes and climatic events have been observed since 1950. Some of these changes have been linked to human influences, including a decrease in extreme cold temperatures, an increase in extreme hot temperatures, Extreme high seas and an increase in the number of intense rainfall events in many areas.

PCC's statements about the extreme events of temperature and precipitation made the study of the global and regional changes of these, a focus of recent scientific research.

2. MATERIALS AND METHOD - STUDY ZONE

The Bourereg watershed is located in north-central Morocco. It covers an area of about 1000 km². It is characterized at the geomorphological level by a decline of the altitudes of the East (Aguelmous) towards the West of more than 1500m (Rabat-Salé) at 0m at the level of the Atlantic Ocean (Picture n ° 1). This basin consists of impermeable formations of primary age. This makes it a disadvantaged area for groundwater and consequently for agricultural irrigation. Thus agricultural activity dominated by cereals is mainly rainfed and subject to climatic variations.

Figure 1: Geographic position of the Oued Bouregreg watershed (Google Earth)

It is located in the South East of the city of Rabat and extends to the chain of the Middle Atlas. This mountain range gives it a diversified relief, and important water potential consisting essentially of runoff or surface water. Hydrologically, it is limited to the North and the Northeast by the watershed of Wadi Beht, a tributary of the left bank of the Oued Sebou, to the South and to the South-East by that of the Oued Grou, tributary of Large basin of the Oued Bouregreg.

The Bouregreg watershed is part of the large basin upstream of the Sidi Mohammed Ben Abdellah dam, which is limited to the north and northeast by the Sebou basin and to the south and south-east by that of Oum Er-Rbie. Geographically,the catchment basin,elongated in direction SE-NW, is between the 33°:03 'and 34 °:06' North and meridian 05 °:31 'and 06 °:43' West (Figure 2).

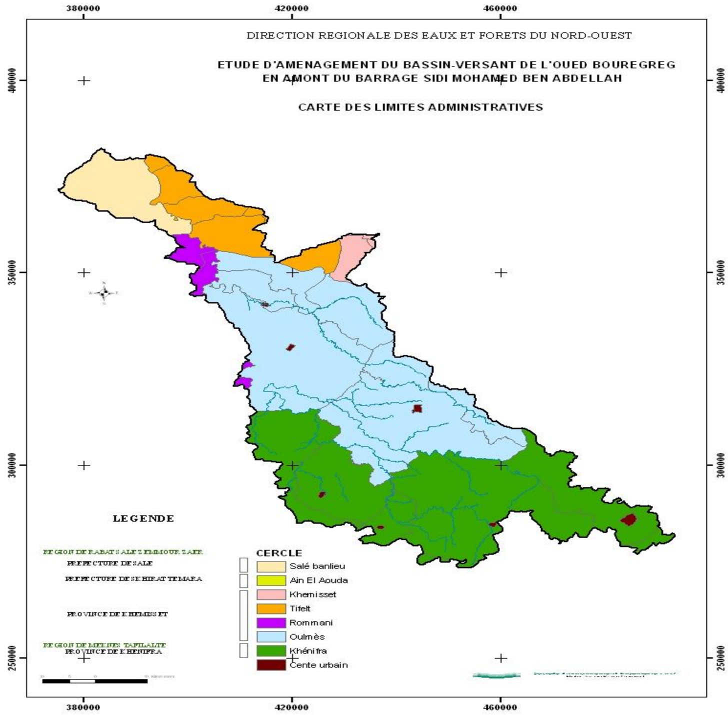


Figure 2: Map of Administrative Boundaries

OBSERVATION DATA

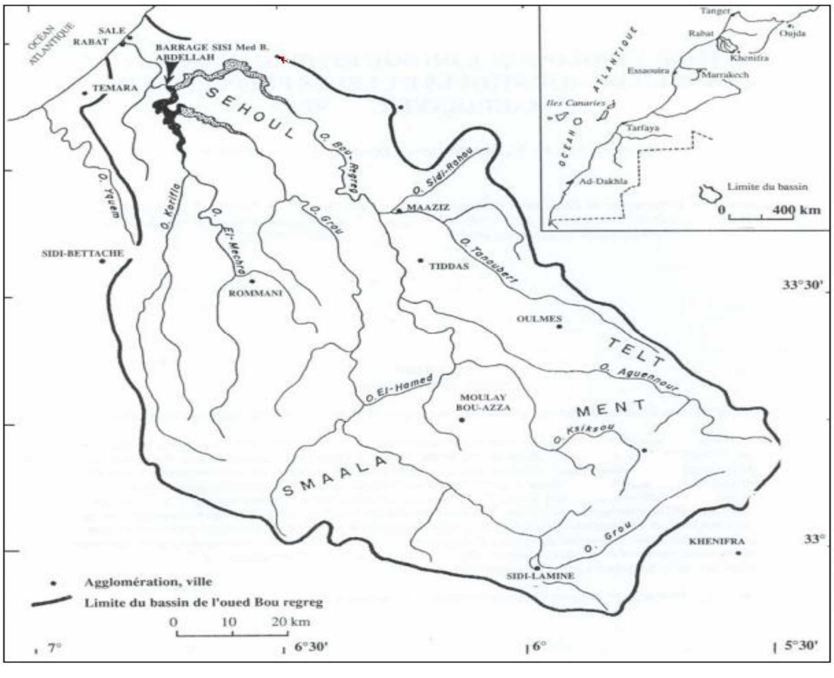


Figure 3: Geographical situation of the Bouregreg watershed
(D'après El Agbani et al. 1992)

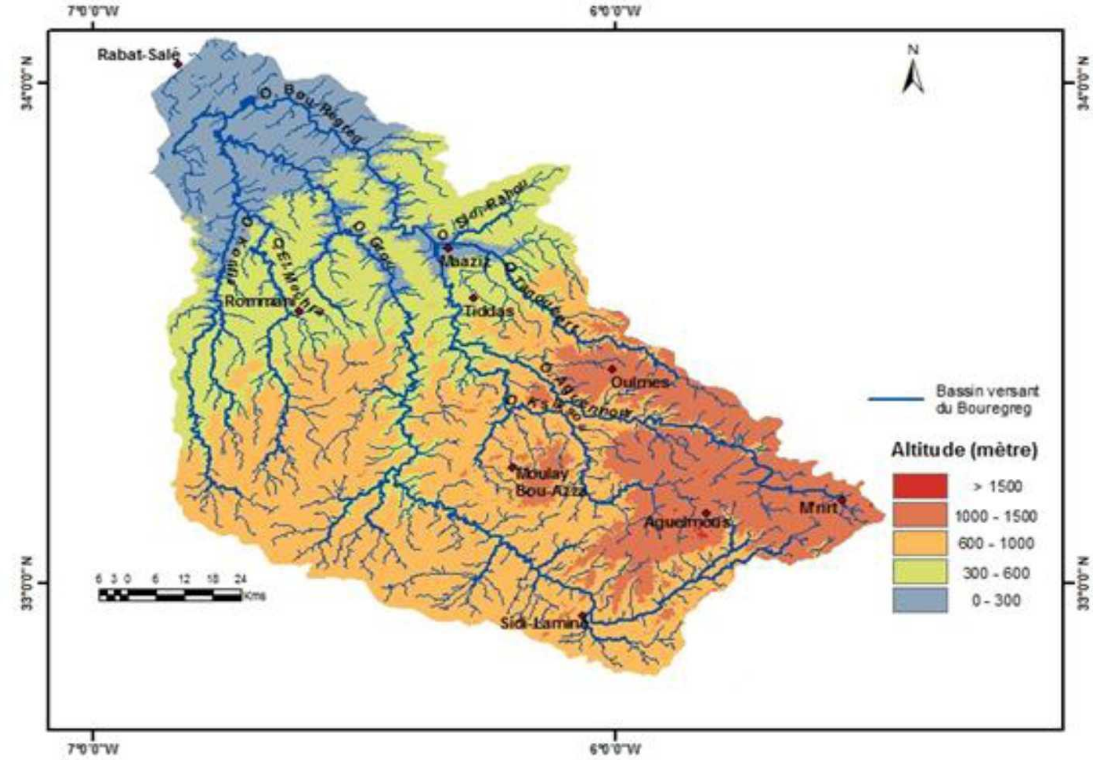


Figure 4: Hypsometric map of the Bouregreg watershed

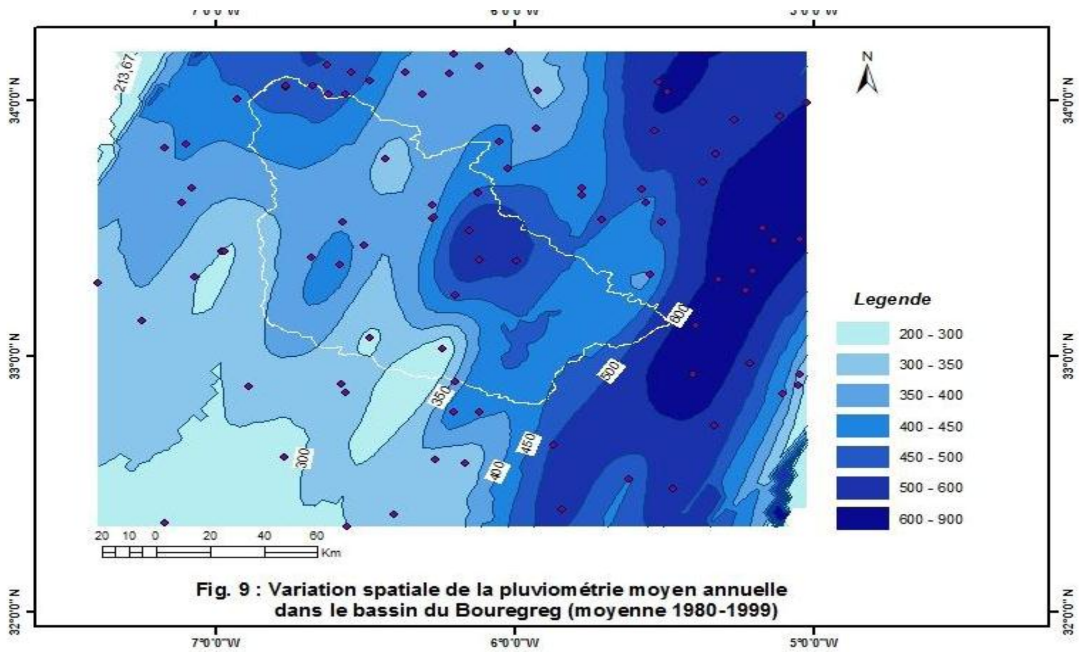


Figure 5: Spatial variation of mean annual rainfall in the Bouregreg basin (average from 1980 to 1999).

(*Source: National Meteorology Directorate and FAO*)

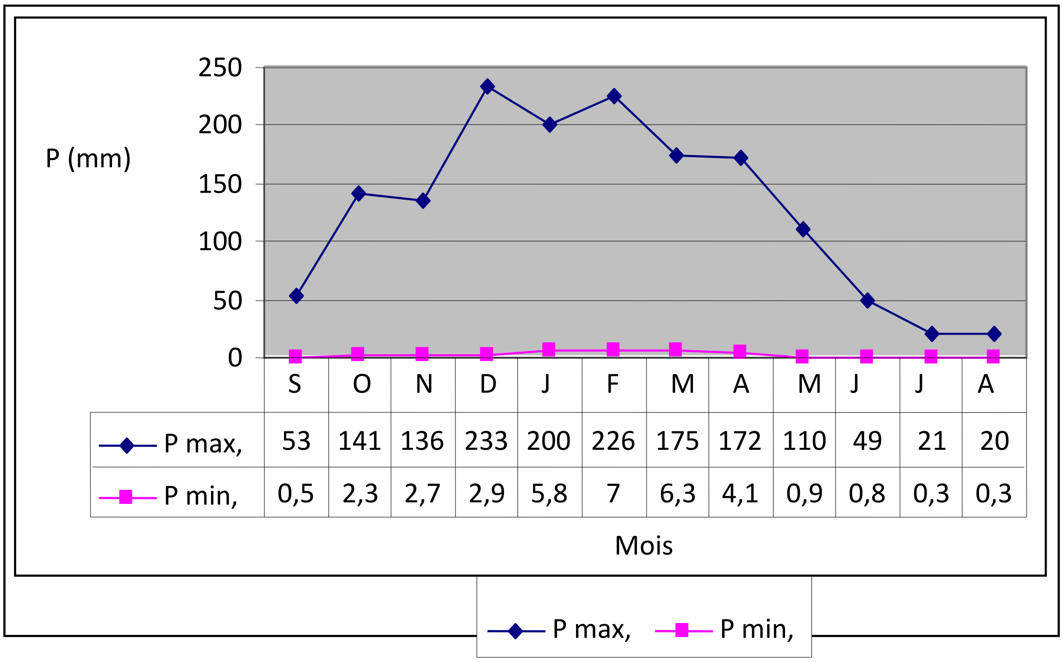


Figure 6: Graphical representation of average monthly precipitation.

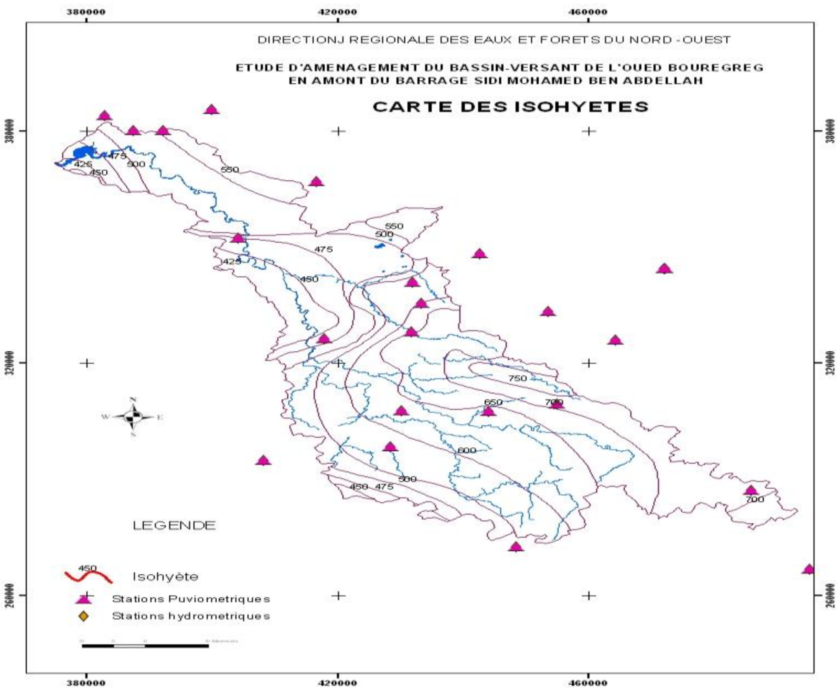


Figure 7: Map of isohyets

UPSTREAM OF THE BASIN

Figure 8: View of Jbel Mzourgane from the highest point of the basin.

Tarhat (Khenifra region) Geographic coordinates : Latitude: 32.99 N Longitude: -5,643 W Altitude: 1036 M.

-TEMPERATURE

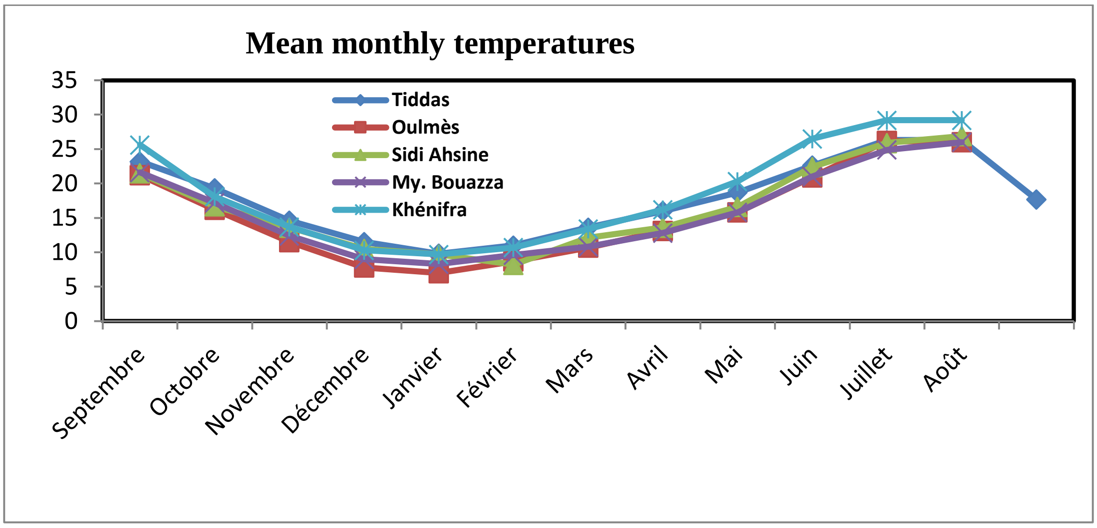


Figure 9: Mean monthly temperatures upstream of the Bouregreg watershed.

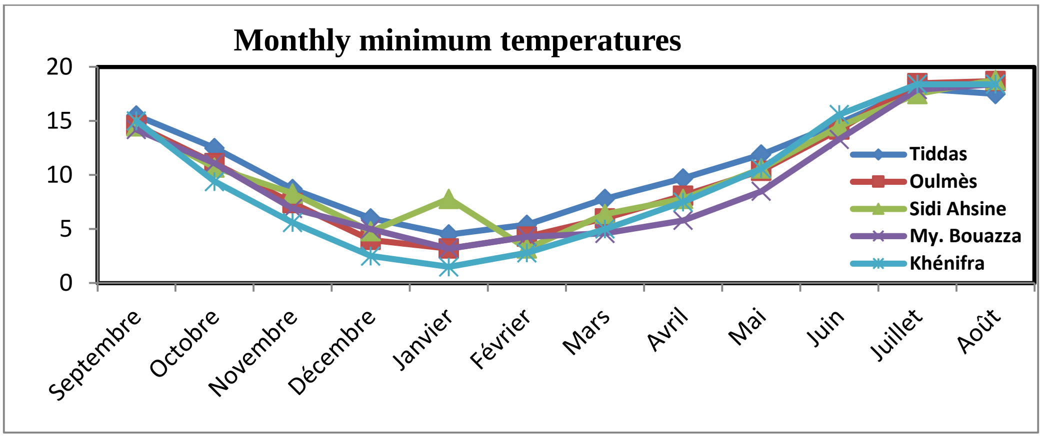


Figure 10: Monthly minimum temperatures upstream of the Bouregreg watershed.

However, the minimum average reaches 3.2° C at Oulmès, Sidi Ahsine and Moulay Bouazza and less than 2 ° C at Khénifra for the coldest month. It is 4.5 ° C in Tiddas

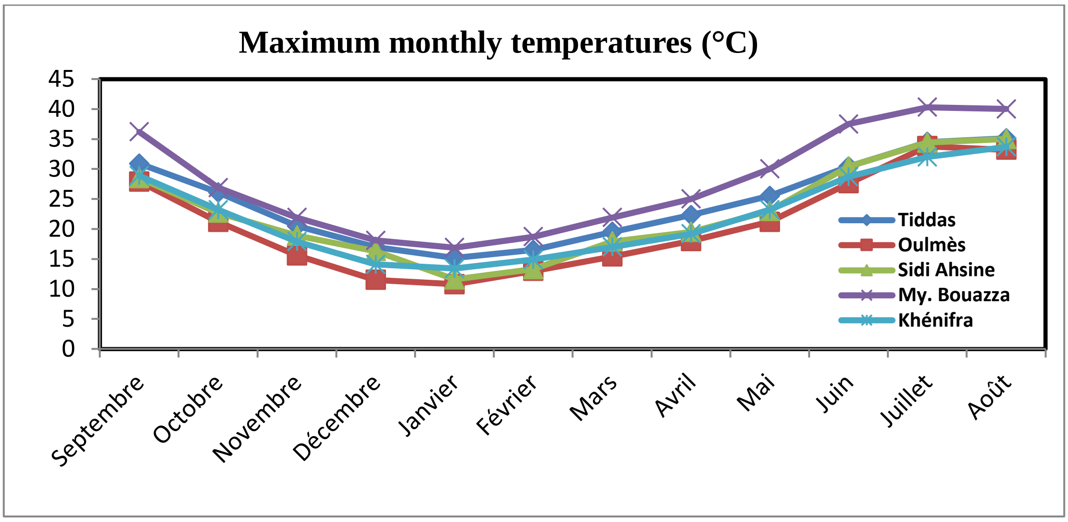


Figure 11: Maximum monthly temperatures upstream of the Bouregreg watershed.

The maximum values for the warmest months are recorded in June, July and August and reach between 30 and 40 ° C.

-THERMAL REGIME

Minimum (m) and maximum (M) temperatures play an important role in the spatial distribution and growth of vegetation. These two parameters indirectly control the level of evapotranspiration of plant species.

Indirectly control the level of evapotranspiration of plant species. The thermal amplitude determined according to the DEBRACH system (1953) is defined as the average extreme thermal amplitude obtained by the difference between the maximum mean temperature (M) of the hottest month and the minimum average temperature of the coldest month m). It makes it possible to characterize the continental climate.

The degree of continentality is expressed as (M-m) as the maximum annual amplitude. As for the type of climate, it is characterized by ((M + m) / 2) as the mean annual temperature value.

Based on the values of the aforementioned indicators, it appears that the thermal regime at the level of the catchment basin is characterized by a moderate semi-continental climate.

- RAIN

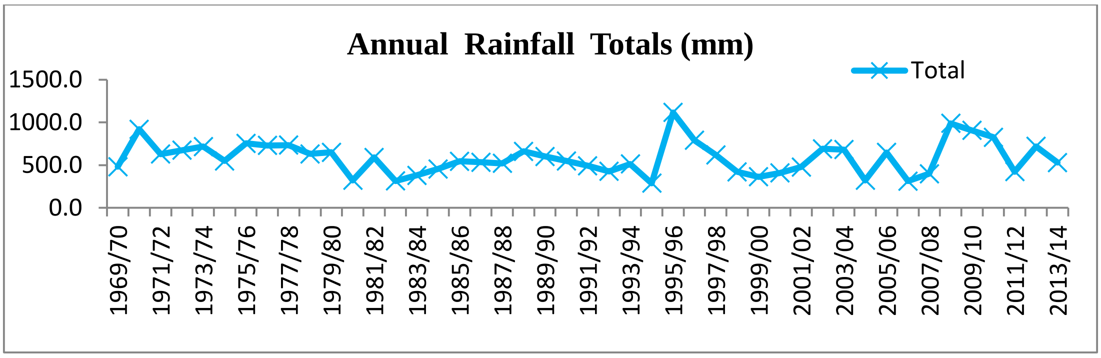


Figure 12: Khenifra annual rainfall for the period (1969-70 to 2013-14).

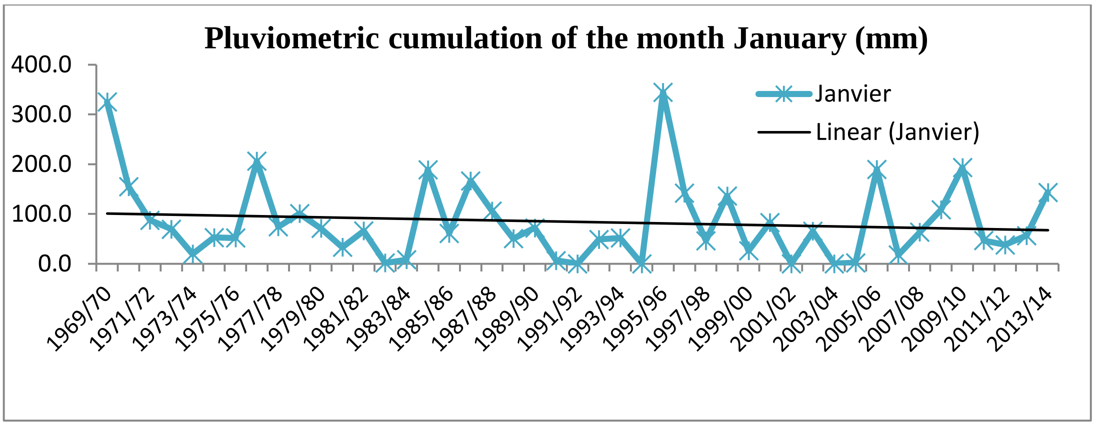


Figure 13: January rain from Khenifra for the period (1969-70 to 2013-14).

- OMBROTHERMIC DIAGRAM

According to the Bagnouls and Gaussen ombrothermic diagrams of the stations for which data are available, it turns out that the dry period corresponds to the months of

June to September for all stations as shown in (Figure 14 and Figure 15).

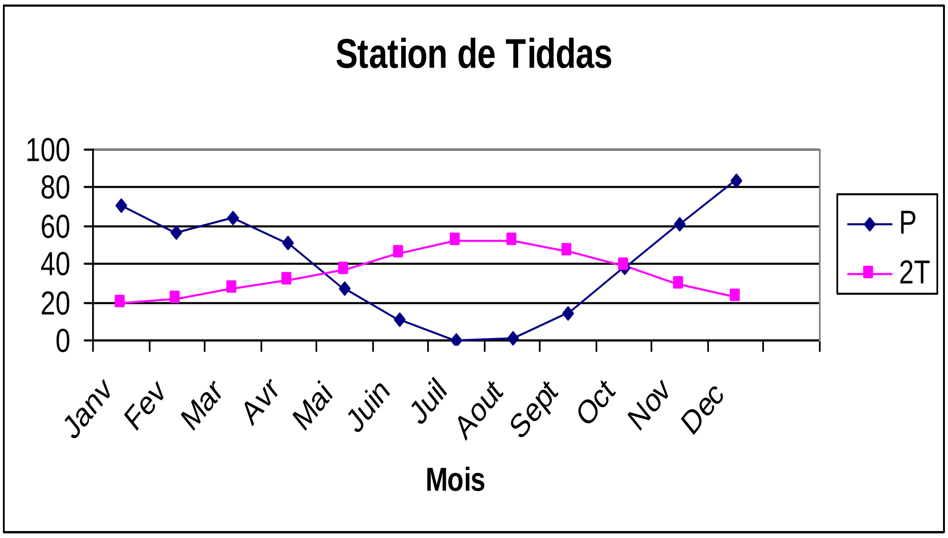


Figure 14: Ombrothermal curve of the Tiddas station.

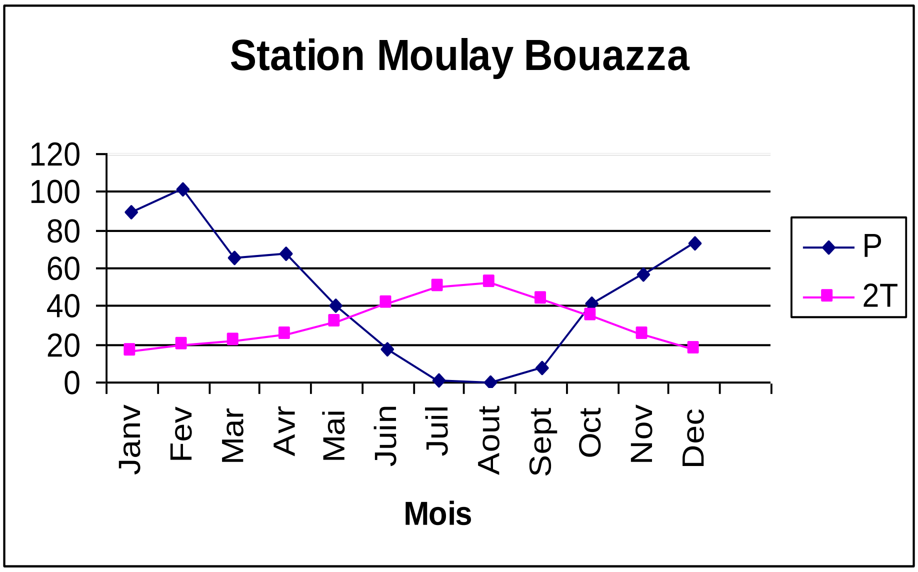


Figure 15: Ombrothermal curve of the Moulay Bouazza station.

Table 1: Frequent meteorological phenomenon upstream of the basin

Extreme Event	Type of Time
-Very Rare Hot	-SW-disturbed time

BASIN CENTRE

Marchouch (Rommani), district of Rabat.

Geographical coordinates: Latitude: 33 ° 60'41 N

Longitude: 6 ° 71'60 W

Altitude: 339 M

Figure 16: Overview of the topography and landscape of Bouregreg Centre.

- **RAIN**

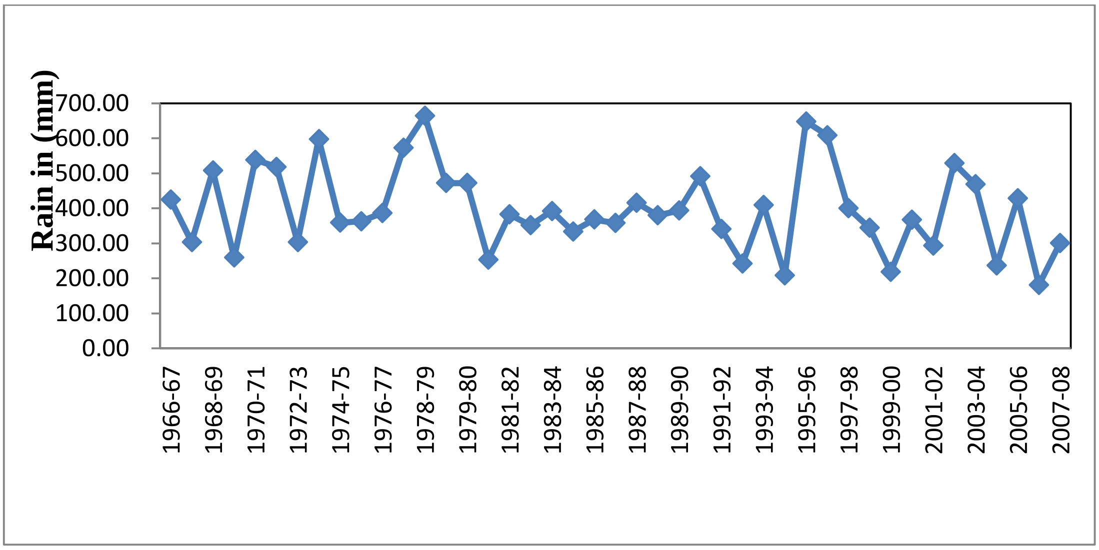


Figure 17: Rainfall evolution at Marchouch (INRA), of the period (1966 - 67 to 2007 - 2008).

-TEMPERATURE

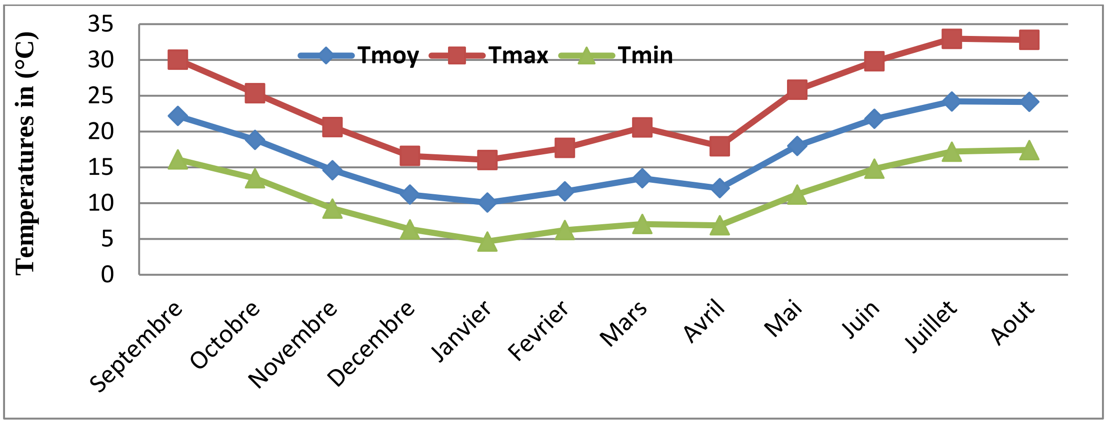


Figure 18: Evolution of Mean Monthly Temperatures (Tmoy, Tmax and Tmin) For the period (2003 to 2008), in Marchouch (INRA).

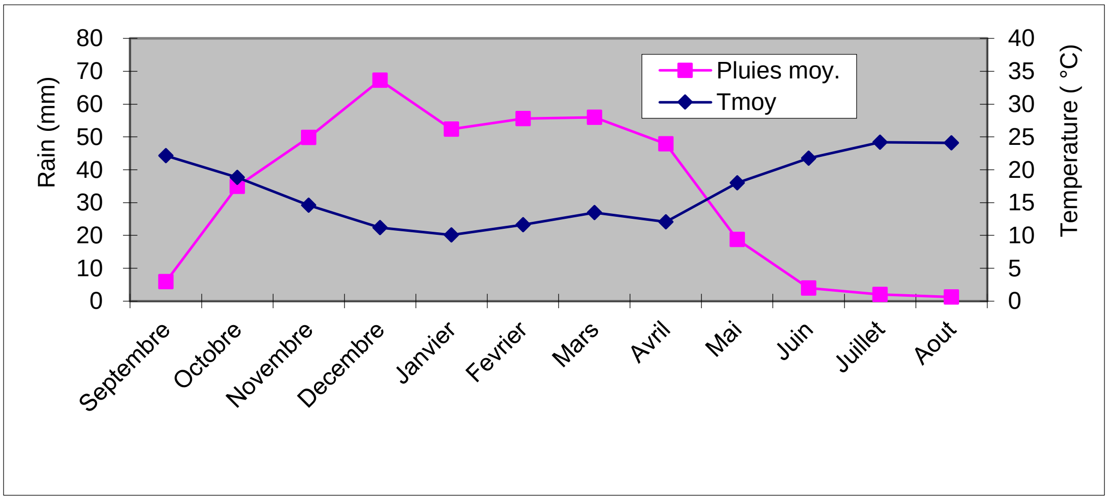


Figure 19: Ombrothermic Diagram of the Experimental Field of Marchouch (INRA).

Table 2: Frequent meteorological phenomenon centre of the basin

Extreme Event	Type of Time
-Very Rare Hot - Disturbed Time by SW	-Chergui: Eastern Regime

DOWNSTREAM OF THE BASIN

Rabat-Sale and Shouls (Sale region)

Coordinates : Latitude : 34 ° 03'00 N
Longitude : 06 ° 45'00 W
Altitude : 74.715 M

Figure 20: Settlement of degraded eastern white cedar in the Shoul region (SBV)

RAIN

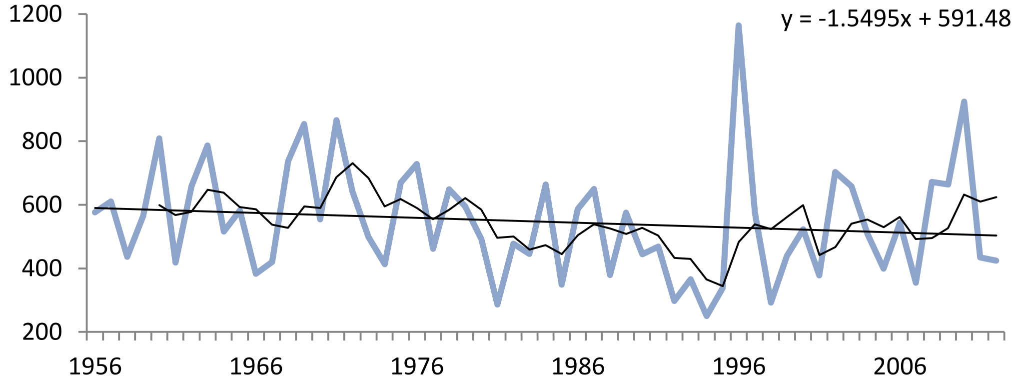


Figure 21: Evolution of annual cumulative precipitation over the period 1956-2012

TEMPERATURE

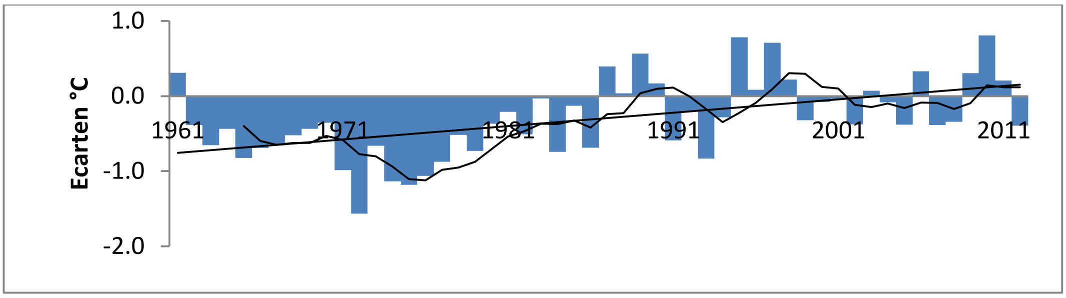


Figure 22: Evolution of the annual mean temperature deviation from normal (1961-2012)

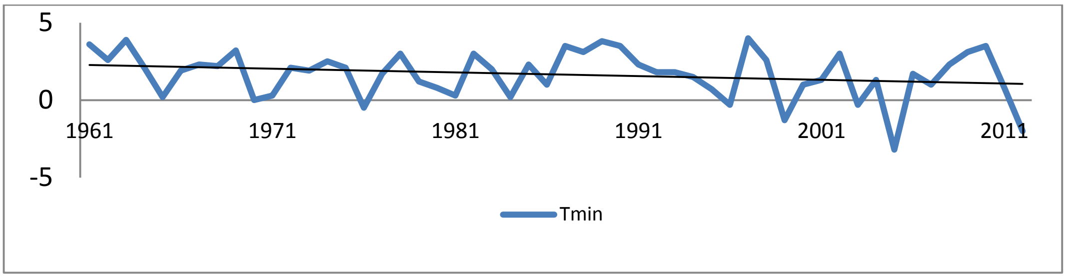


Figure 23: Evolution of annual minimum temperatures (1961-2012)

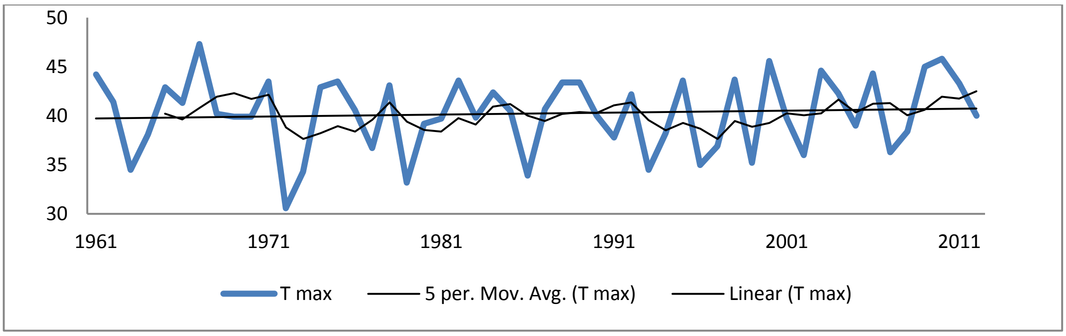


Figure 24: Trends in annual maximum temperatures (1961-2012).

Table 3: Frequent meteorological phenomenon downstream of the basin

Extreme Event	Type of Time
-Very Rare Hot –disturbed Time by SW	-Chergui : Eastern Regime

Figure 25: Portion of the reservoir of the SMBA dam where the Oued Bouregreg

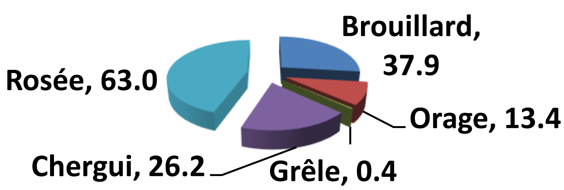


Figure 26: Annual number of days of the most important weather events From The region of Rabat.

Table 4: Climatic classification according to the Martonne and Quotient index from Emberger to Rabat-Sale

Martonne's index 1961-2012	Quotient of Emberger 1961-2012
19.8 (the boundary between semi arid and subhumid)	**94 (Subhumid)**

BIOCLIMATIC SYNTHESIS

- Emberger.Q2 Pluviothermal Quotient

Emberger's quotient makes it possible to characterize the Mediterranean climate from an ecological point of view (Sauvage C.H., 1963). This quotient is defined as follows:

Q2 = 1000P / ((M + m) * (M-m) / 2)

P: average annual precipitation (mm)

M: Average daily maximum of the hottest month (degree Kelvin)

M (° K) = t ° C + 272.6

M: Average of daily minimums of the coldest month (degree kelvin)

M (° K) = t ° C + 272.6

This quotient makes it possible to distinguish a variety of bioclimatic stages prevailing in the catchment area. These bioclimatic stages vary from semi-arid to sub-humid with fresh to hot variants. The main bioclimates encountered in the basin are described in (Table 5).

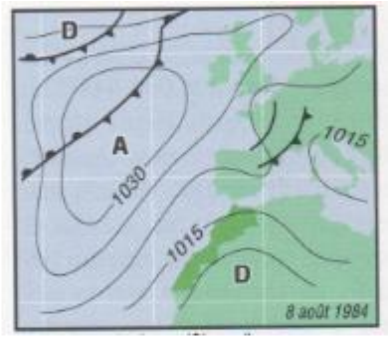
Table 5: Bioclimate of the watershed

Station	**Max (°C)**	**min (°C)**	**Q2**	**Bioclimate**
Rabat	28.4	8.1	83.99	Hot subhumid
Rommani	36.0	4.0	37.82	Semi arid temperate
Oulmès	33.8	3.2	69.49	Temperate Subhumid
Khénifra	40.3	1.2	55.0	Semi arid fresh
Tiflet	35.8	5.6	56.4	Semi arid temperate
My Bouazza	33.7	3.2	67.5	Temperate Subhumid
Sidi Ahsine	35	3.2	79.6	Temperate Subhumid
Tiddas	35.1	4.5	53.4	Semi arid temperate
Khémisset	36	5	62,0	Temperate Subhumid
Timeksaouine	34	4	64.2	Temperate Subhumid

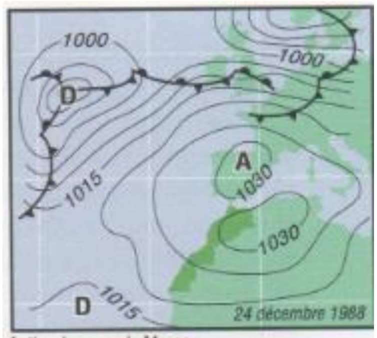
Source: CNRF, Rabat and study documents

Table 6: Characteristics of the synoptic regimes identified

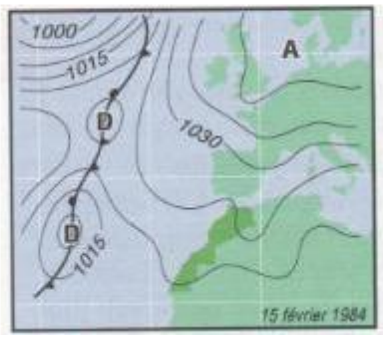
Synoptic regime	**Characteristics**
Eastern regime of Chergui type	The axis of the zonal ridge is on the north of Morocco. The country is subject to an eastern or northeastern regime called Chergui and masses of hot and dry air invade the country.
Disturbed North-East Time	Morocco is subject to direct air evacuation from Northeast, after having crossed the Mediterranean



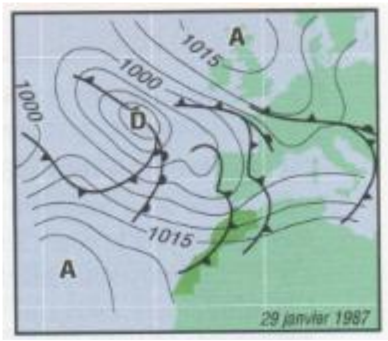
Saharan depression (chergui): good winters very high temperatures



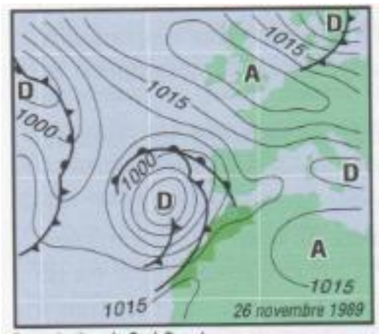
Anticyclone on Morocco: good winter weather



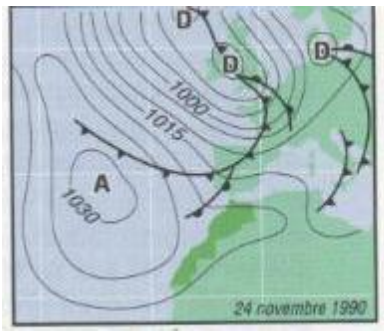
Very cold weather in the north-east rain disturbances



Disturbances in the west: succession rainy



Southwestern Disturbance



Northwestern Disturbance

Figure 27: Position of air masses in Morocco

(Source: Atlas of Morocco, 2002)

- WIND

The analysis of wind dominance in terms of intensity and direction in the northern region was based on hourly data for the last five years 2009-2013.

Regarding the wind direction in Rabat- Sale, we can see that the wind is manifest in several directions with more significant percentages in the north sector and the west sector: the north direction totals a maximum of 10.3% of which 67% of the winds moderate. In second position comes the south direction and the south direction is with respectively 8.3% and 8.2%. As for strong winds, they occur mainly in the South West sector with a percentage of 40%. The maximum peak recorded is 119 km / h on 19/12/1973 with a southwesterly wind (Figure 28).

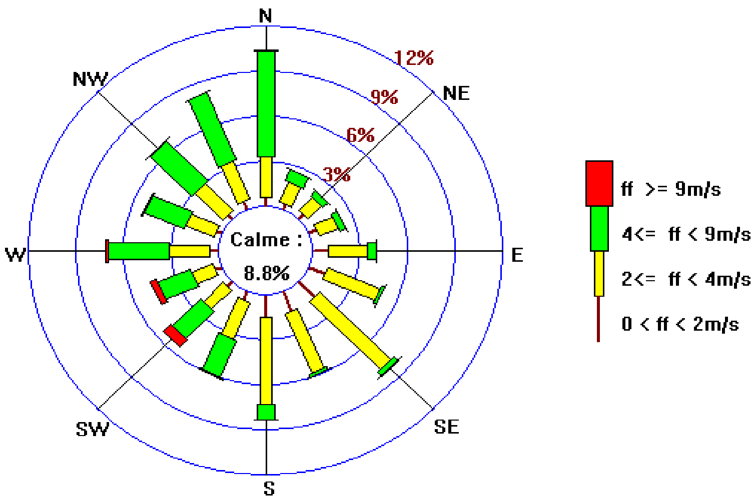


Figure 28: Annual wind rose for the period 2009-2013

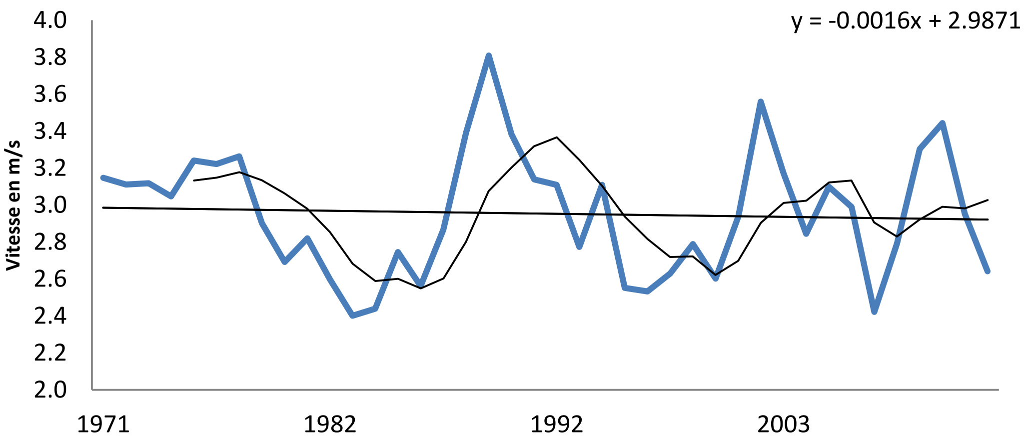


Figure 29: Annual evolution of the average wind in the region of Rabat- Sale

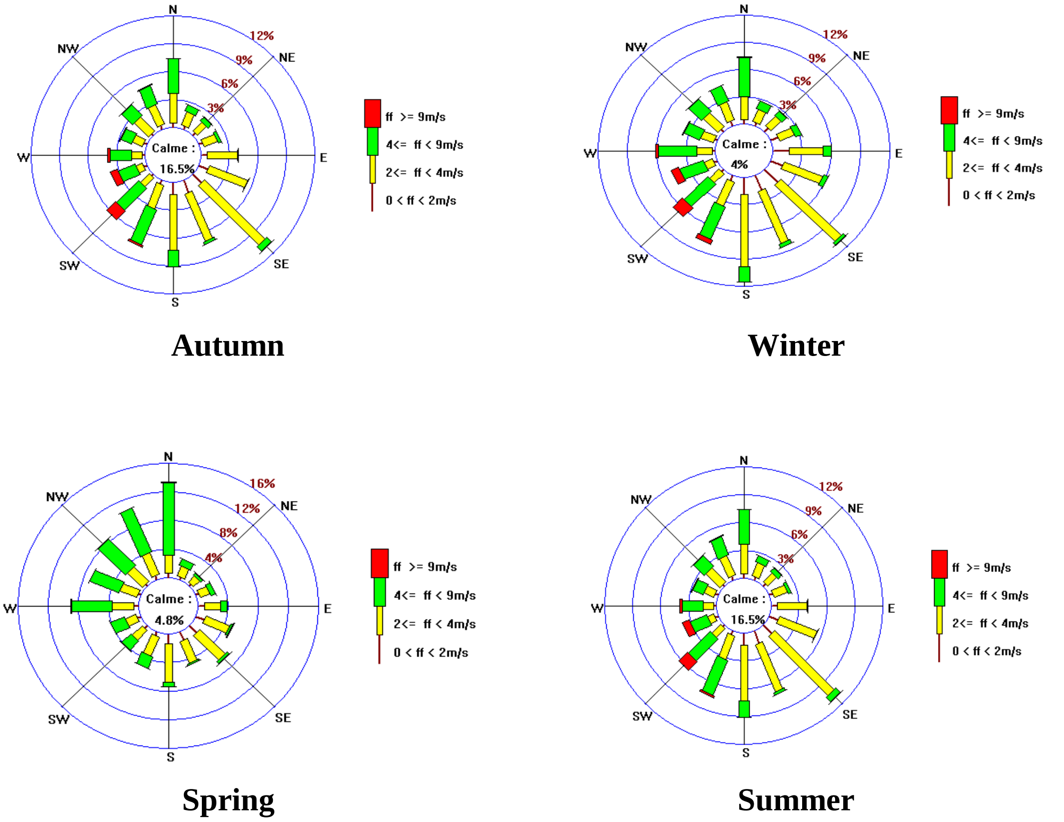


Figure 30: Roses of the Winds by Season (2009-2013) to the North Region

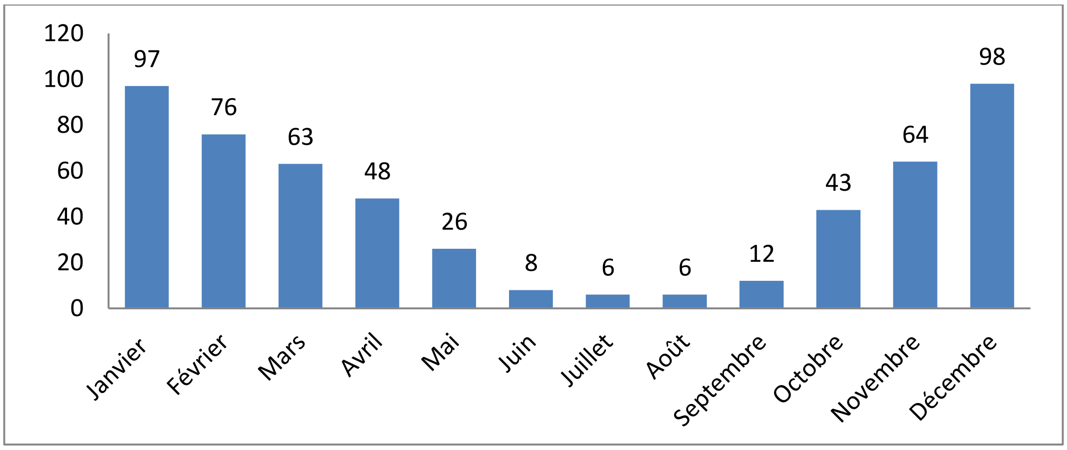


Figure 31: Number of days with strong and violent winds during 1961-2012

- HUMIDITY

The figure (Figure 32) illustrates the evolution of the monthly average of maximum and minimum humidity for thirty years. It is noted that the maximum difference between the maximum and minimum average humidity is of the order of 39% with

95.6% as the maximum value in the month of February and 55.1% in the month of April.

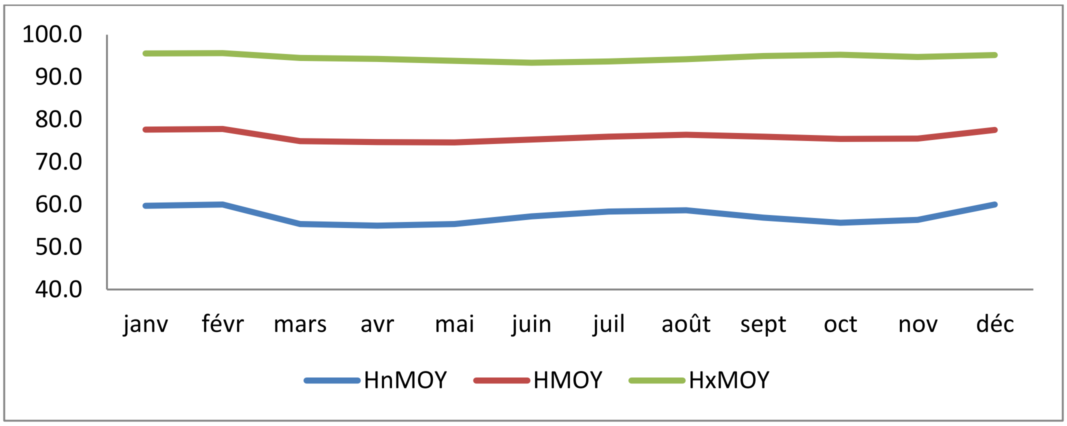


Figure 32: Monthly average of maximum and minimum humidity in the Rabat region.

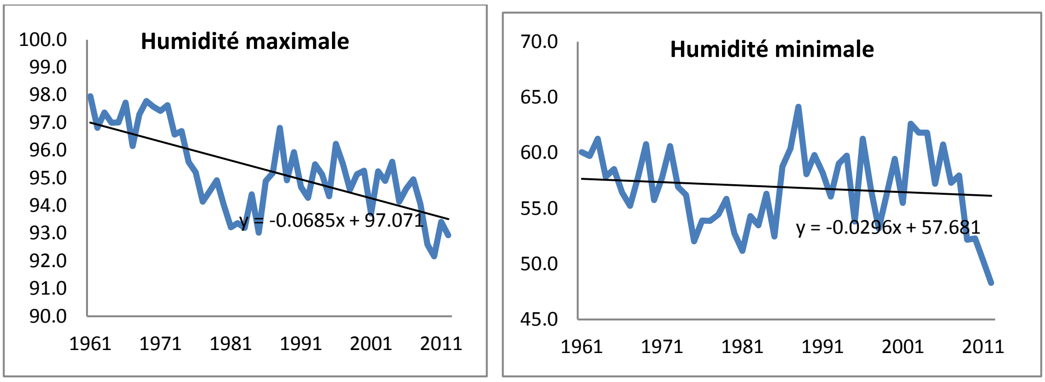


Figure 33: Evolution of minimum and maximum humidity during the period 1961-2012.

The (Figure 33) shows a noticeable downward trend for maximum moisture in Rabat especially during the 1980s, and a slight decrease for minimum moisture.

DATA FROM THE MCG MODEL

- Model HadCM3

HadCM3 (Hadley Center Model 3) from www.worldclim.org/futurdown.htm and retrieve them by ArcGis software for viewing and display, then compare them with current monthly climate data for the year (2007-2008) for the experimental site of Marchouch, INRA.

<u>Scenarios (SRES)</u>

Scenario B2:

This is an optimistic scenario that describes a world where the emphasis is placed on local solutions, in a sense of economic, social and environmental viability. The world population is growing steadily but at a slower pace than in A2. There are intermediate levels of economic development and technological change is slower and more diverse. In our research, we opted for scenarios A2 and B2, these two scenarios are the closest to the trajectory of the evolution of Moroccan society and Changes associated with climate indicators (Gommes et al., 2008). They are widely used at present in the modeling work carried out with the most complete coupled models.

- Model CNRM-CM5

The new version of the CNRM-CM global circulation model was developed by CNRM-GAME (National Meteorological Research Center-Meteorological Atmosphere Study Group) and Cerfacs (European Center for Advanced Research and Training) To contribute to Phase 5 of the Coupled Model Intercomparison Project (CMIP5). The proposal of the study is to describe its main characteristics, an assessment of the preliminary demand of the average climate. CNRM-CM5.1 includes the ARPEGE-climate atmospheric model (v5.2), the NEMO Ocean model (v3.2), the ISMA earth surface and the GELATO (v5) sea ice model coupled across the OASIS system (v3).

<u>RCP Scenarios</u>

In the context of the preparation of the IPCC 5th Assessment Report, an international panel of experts has defined four baseline scenarios, referred to as representative effect concentrations (RCPs) for Effect Gases (Representative Concentration Pathways) Greenhouse gases, ozone and aerosol precursors for the 21st century and beyond. These scenarios may correspond to more or less global efforts to reduce GHG emissions.

For each of these four "representative profiles", climatologists deduce the climatic conditions and impacts of the associated climate change. At the same time, sociologists and economists work on scenarios with various socio-economic development features and various adaptation and mitigation strategies. Five sets of scenarios, named SSP (for Shared Socioeconomic Pathways), have thus been defined. Such an approach allows parallel and coherent work by climatologists and economists.

The IPCC has decided to define new scenarios to better take into account this new context and allow economists and climatologists not to work in a sequential but parallel fashion. Finally, unlike the SRES scenarios, these new scenarios are not defined by the IPCC itself, but have been established by the scientific community to meet the needs of the IPCC.

The approach followed for the definition of the scenarios for the 5th report is therefore different from the previous one. Beyond the conception of new scenarios, it is a true methodological turn that operates the scientific community.

Previously, the analysis was conducted following a sequential logic. Reflection started from a bundle of "possible futures" for our societies, integrating a wide range of determinants - changes in national economies, technological offer, energy choices, demographics, individual behaviors, and so on.

To gain speed and responsiveness, the scientific community is now applying a different method. The scientists defined ex ante representative profiles of concentrations of greenhouse gases, ozone and aerosol precursors representative of an increase in the energy balance: the representative pathway (RCP).

Based on these reference profiles, the teams work simultaneously and in parallel: climate scientists produce climate projections using CPR as input, while sociologists and economists develop scenarios resulting in emissions of effluent gases Greenhouse gases consistent with CPR (Figure 34).

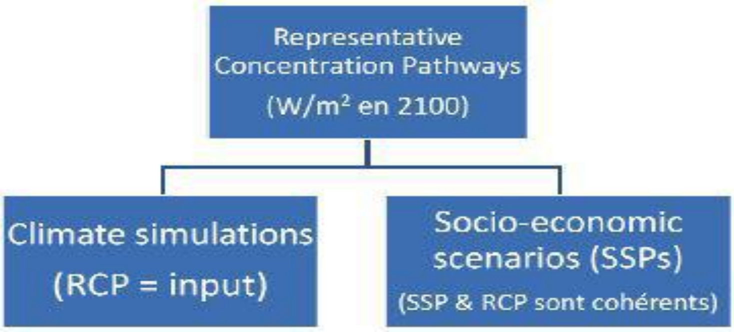


Figure 34.

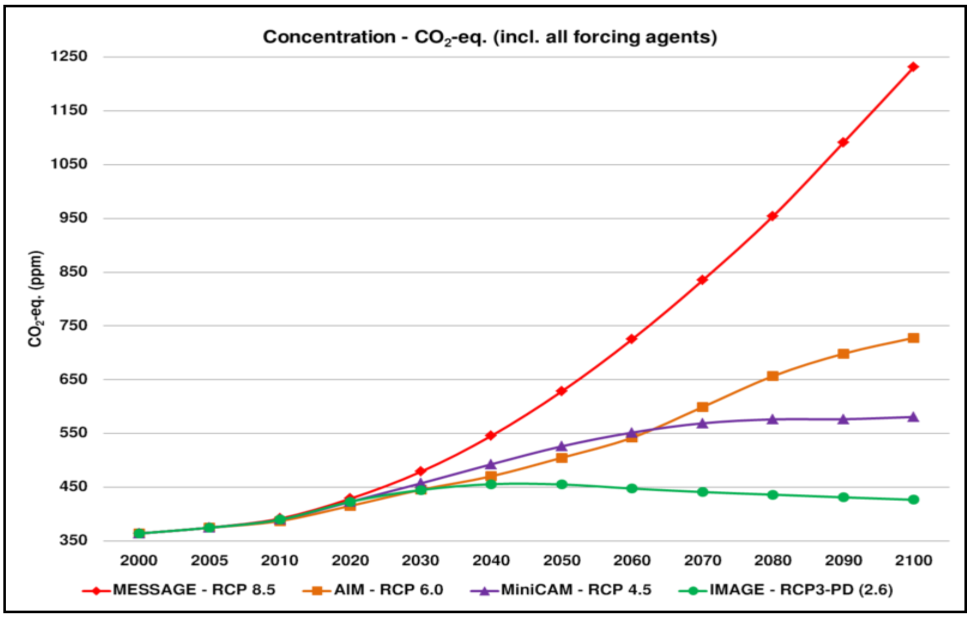


Figure 35: Concentration of CO2 with all forcing agents

The RCP profiles are described until 2300, while the SRES scenarios of the previous IPCC work stopped in 2100.

- DOWNSCALING

For simulations at a regional level, a downscaling method is used (Figure 36) using the development of regional models, with resolutions of 10 to 50 km which take into account the topography more finely. These models are themselves relayed

By means of local impact or adaptation models, a horizontal resolution of the order of one kilometer.

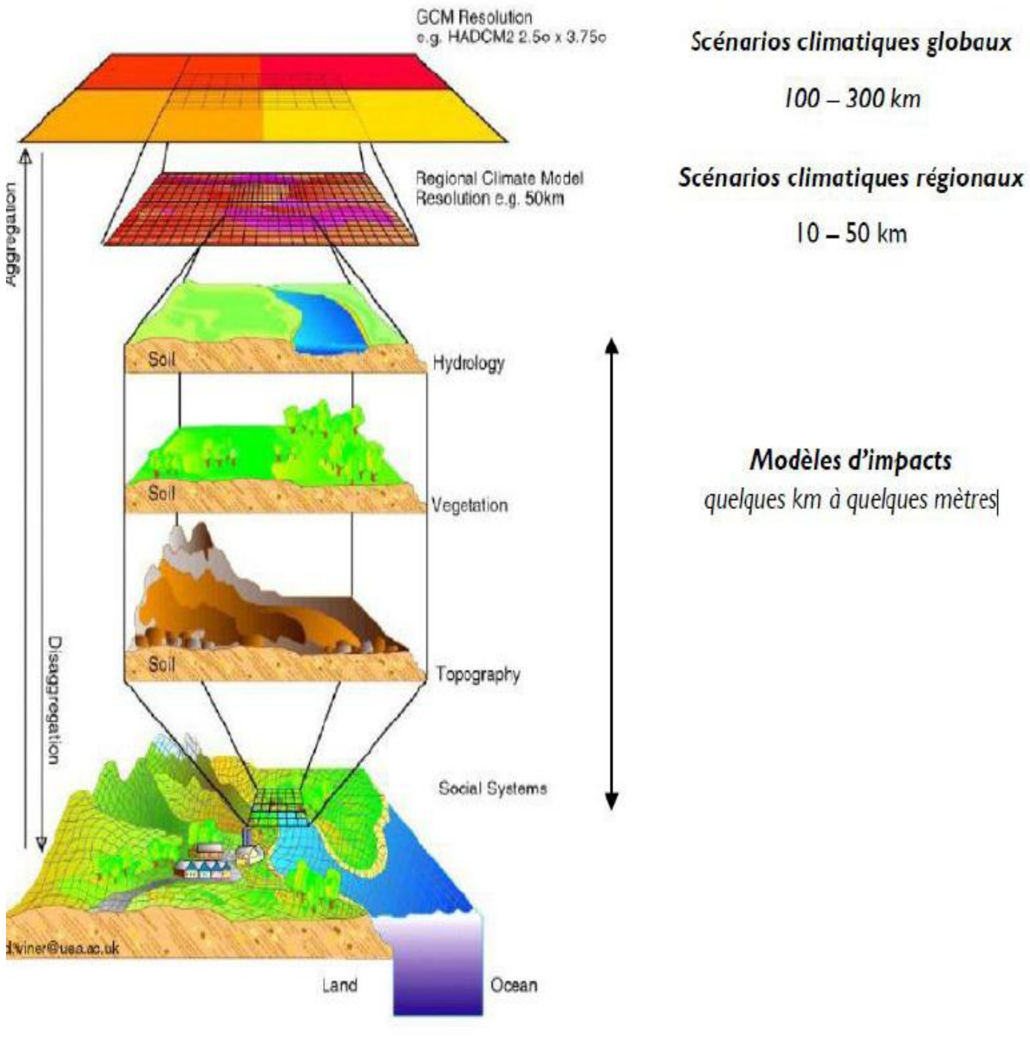


Figure 36: Scales of the different scenarios and models used in downscaling (according to S. Planton).

3. RESULTS AND DISCUSSION

In this study, monthly averages of meteorological data (Rain and Temperatures: Tmax and Tmin) of the Tarhat hydro-meteorological station (Khenifra-ABH) were used for the baseline period (1950-2000) and also for future projection periods 2050 (2041-2060) and 2070 (2061-2080). The mean annual rainfall over the period (1966/67-2007/2008) and the monthly mean temperatures (Tmoy, Tmax and Tmin) for the period (2003-2008) of the Weather station Marchouch (Rommani-INRA), and also for the projected future period 2020 compared to the period (2008-2009). For the downstream basin, annual precipitation totals were used for the period (1956-2012) and the minimum and maximum annual temperatures for the period (1956-2012).

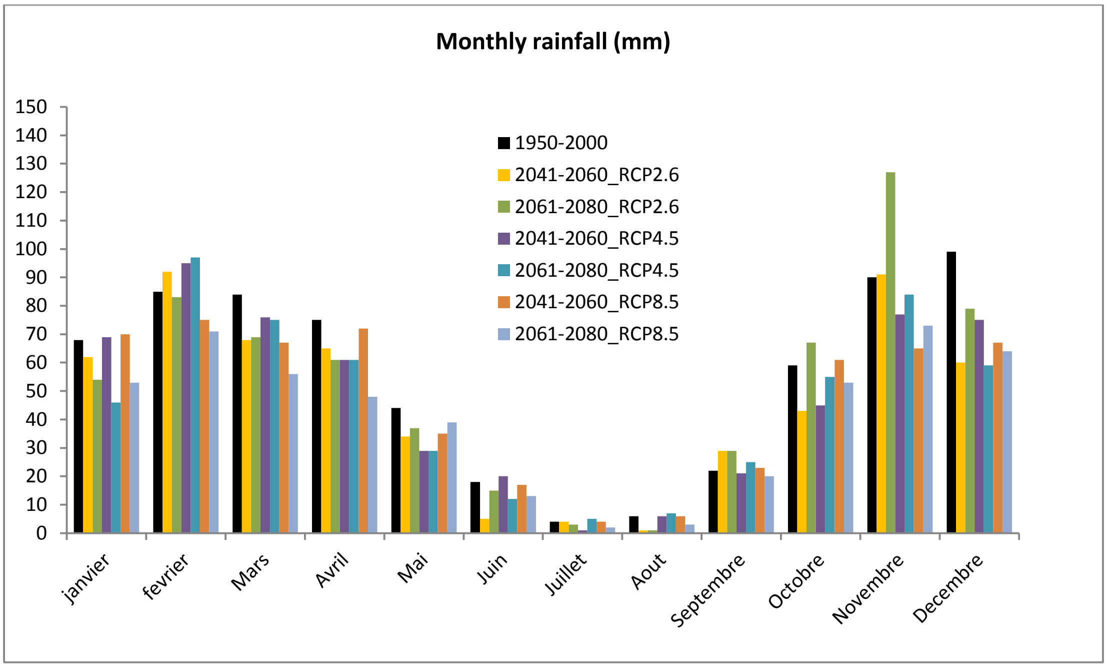


Figure 37: Monthly rainfall of Tarhat (Khenifra region) for the past period (1950-2000) And Future periods (2041-2060) and (2061-2080) for the RCPs (2.6, 4.5 and 8.5).

We note that:

Trend in winter rainfall decrease (Dec-Janv) for scenario RCP2.6, while for scenarios RCP4.5 and RCP8.5 there is a decrease for December and no significant change for January.

Diminution des pluies durant la saison du printemps (Mars-Avril-Mai) et le début de la saison hivernale pour les trois scénarios à l'exception du mois Novembre pour le scénarios RCP2.6 où on a une nette augmentation des précipitations moyennes durant la période 2061-2080.

Les deux mois Novembre et Février sont les plus humide par rapport à la période de référence, les scénarios RCP2.6 et RCP4.5 prévoit la conservation de cette propriété à l'exception du scénario RCP8.5.

The RCP8.5 scenario predicts a decrease in precipitation during the months of November to March with the exception of the month of January.

It is also found that the average precipitation for the RCP4.5 scenario remains almost stationary during the two projection periods 2041-2060 and 2061-2080 during the end of the wet season. This can be interpreted in the light of the fact that scenario RCP4.5 provides for stabilization of CO2 concentration from the year 2050 (Figure 37).

There is a low variability in monthly rainfall for the wet season (October-April). For the future periods (2041-2060 and 2061-2080) for the RCPs (2.6, 4.5 and 8.5) compared to the base period (1950-2000). However, the graph illustrates a cumulative rainfall over the future for the wetter months in the region (November and February) compared with the previous period and also a decrease in monthly rainfall cumulative for the critical growing months of cereal farming of the region (February-May).

The rainfall correlation between 2050 and the past (1950-2000) is 93.15% and the mean deviation is -8.33, the correlation between 2070 and the past is 91.27% and the mean deviation is -2.42, and the correlation between 2050-2070) is 93.01% and the mean deviation is 5.92.

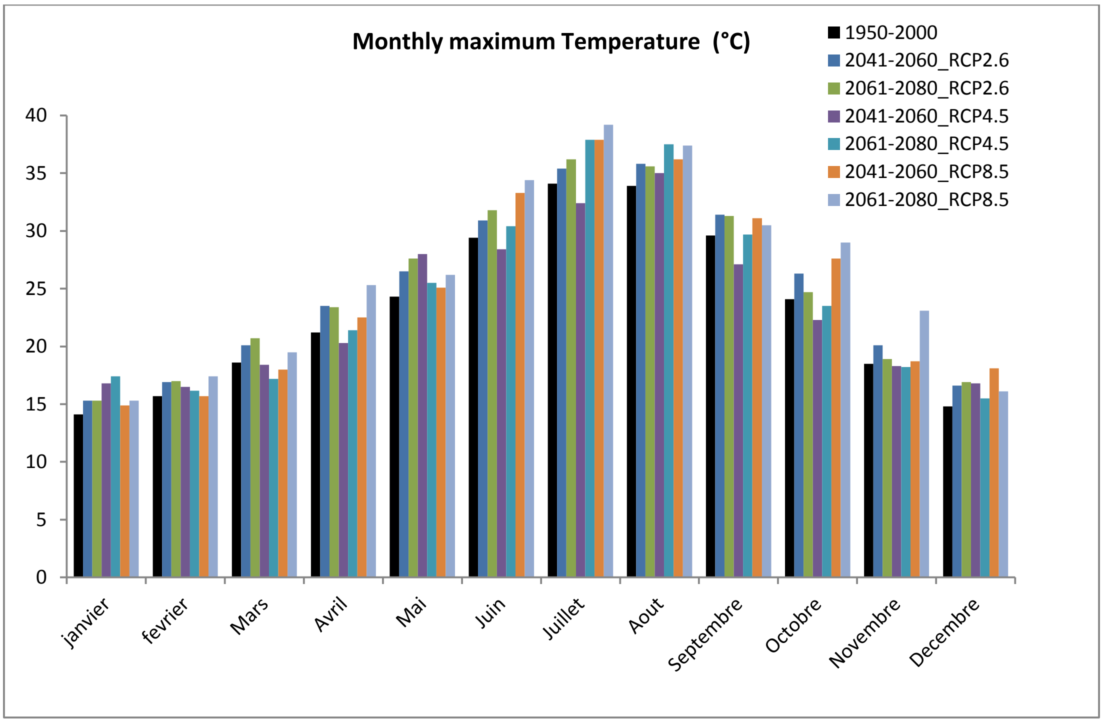


Figure 38: Maximum monthly temperatures of Tarhat (Khenifra region) for the period (1950-2000) and future periods (2041-2060) and (2061-2080) for The RCPs (2.6, 4.5 and 8.5).

General tendency to increase the maximum temperatures in relation to the reference period.

The increase is more marked during the summer season (June-August), and less significant during the months of February, November and December.

Scenario RCP4.5 provides for maximum temperatures lower than those predicted by scenario RCP2.6 during the start and end of the wet season.

In most cases, RCP8.5 provides for a very marked increase in maximum temperatures, especially during the projection period 2061-2080.

The graph shows an increase in monthly maximum temperatures for periods (2041-2060 and 2061-2080) for the RCPs (2.6, 4.5 and 8.5) for the RCP 8.5 scenario compared to the reference period (1950-2000). This will give the wet period (October-April) warmer.

The correlation of maximum temperatures between 2050 and the past period (1950-2000) is 99.86% and the mean deviation is 23.36, the correlation between 2070 and the past is 99.46% and the mean deviation is 24.20, and the correlation between 2050-2070) is 23.19% and the mean deviation is 23.19.

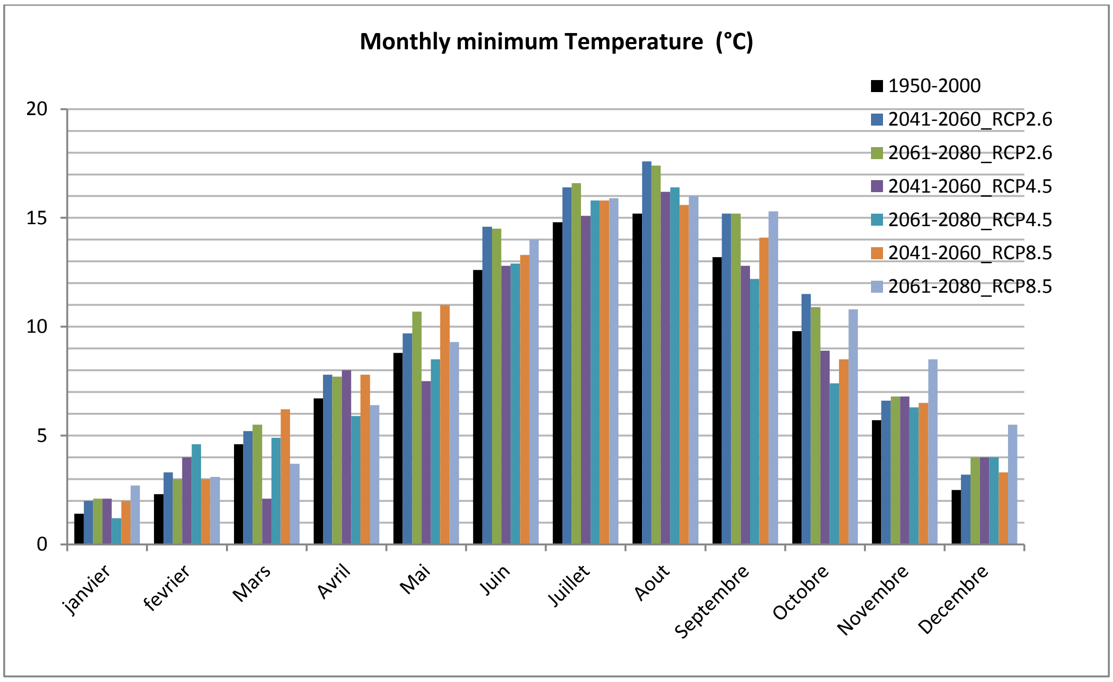


Figure 39: Monthly minimum temperatures of Tarhat (Khenifra region) for the period (1950-2000) and The Future Periods (2041-2060) and (2061-2080) for the RCPs (2.6, 4.5 and 8.5).

General tendency to increase minimum temperatures relative to the reference period. The increase is more marked during the summer season (June-August), and less significant during the months January and November.

The RCP2.6 scenario foresees a more significant increase during May-October than the other scenarios.

Scenario RCP8.5 provides lower minimum temperatures during February-March-April.

Scenario RCP8.5 provides for a more marked increase in minimum temperatures during September - January.

The figure above shows an increase in the Monthly Minimum Temperatures for the periods (2041-2060 and 2061-2080) of the RCPs (2.6 and 8.5) compared to the last period (1950-2000). This will make the wet period very hot.

The correlation of minimum temperatures between 2050 and the past is 99.87% and the mean deviation Is 8.36, the correlation between 2070 and the past is 99.85% and the mean deviation is 8.34, and the correlation between (2050-2070) is 99.69% and the mean deviation is 8.13.

Table 7: Comparison of current maximum temperatures for the period (2008-09) and future of the year (2020) of Domaine Exp. Marchouch, INRA.

	Present	**Future**
	2008-2009	2020
Months	T max	T max
September	28,22	28,40
October	22,44	22,80
November	17,67	16,30
December	15,25	13,10
January	14,33	15,30
Febrary	17,54	17,10
March	20,59	19,40
April	20,26	20,50
May	26,26	26,90
June	30,86	30,70
Jully	29,22	34,60
August	31,44	33,50
Average/year		23,22

Table 8: Comparison of current minimum temperatures for the period (2008-09) And future of the year (2020) of Domain Exp. Marchouch, INRA.

	Present	**Future**
	2008-2009	2020
Months	T min	T min
September	15,70	16,60
October	12,10	13,30
November	7,60	9,50
December	6,40	6,80
January	5,90	5,20
Febrary	7,40	6,20
March	9,80	7,40
April	7,00	9,30
May	11,70	12,30
Juine	16,10	15,90
Jully	15,40	17,60
August	16,20	17,90
Average/year	10,94	11,50

For temperatures (T max and T min), depending on the model of climatic scenario B2, there will be an increase in temperature (+1 to 2 ° C). The study area will become warmer in the future

Table 9: Comparison between the current rains of the period (2007-08) and the future of the year (2020) of the Experimental Domain Marchouch, INRA.

	Present	**Future**
Months	Rain	Rain
	2007-2008	2020
September	1,40	7
October	15,94	10
November	67,52	17
December	14,85	8
January	52,87	2
Febrary	45,44	2
March	13,07	3
April	44,74	2
May	45,25	2
Juine	0,00	0
Jully	0,00	1
August	0,00	3
Cumulative/year	301	57

For rainfall, according to the proposed B2 model for the study area, it appears that in the future there will be less rainfall (about less than 80%). It is a strong aridity that will settle in the region of the Experimental Field Marchouch, INRA, according to the climatic scenario.

DISCUSSION

According to the RCP scenarios (2.6, 4.5 and 8.5), the study area will become more arid in the future, which will have direct and negative effects on crops and especially cereal yields and also on water resources. This is consistent with the results obtained in the "WB / FAO / INRA / DMN" report prepared by the World Bank's study on Morocco (Gommes et al., 2009).

4. CONCLUSION

Influence on the spatial-temporal distribution of precipitation. The hydrological regime of the whole Bouregreg basin is characterized by a great inter-annual variability marked by the alternation of the wet and dry sequences, intercalated by years of high hydraulicity or severe drought. The Bouregreg basin has a water deficit of 8%, and is expected to have it by 2020.

This situation is likely to deteriorate as a result of climate change and worsening of extreme events, particularly the significant reduction in rainfall and generalized drought. Indeed, despite the favorable rainfall of the last two years, the threat of drought still hangs over the country as in the periods 1980-1985 and 1990-1995 and 1998-2002 during which almost all the watersheds were in a deficit situation.

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