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Rainfall - Temperatures Fluctuations in the stream Mikkes basin (Morocco)

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Abstract: The stream Mikkes is located in centre-north Morocco, an area of 1600 km^2 and has been receiving average rainfall of 575 mm annually, for 42 years (1968-2009). This basin, through three different structural parts: the El-Hajeb Ifrane Tabular in the south, the Saïs basin in the centre and the Prerif - Prerif Ridges in the north. This article, based on a statistical study of rainfall - temperature fluctuations recorded in the Mikkes basin between 1968 and 2009. In general the monthly rainfall - temperature pattern in various Mikkes stations (1968-2009) are similar, but Tabular stations have shown higher rainfall and low temperatures compared to other stations. This suggests the effect of an altitude gradient. These seasonal fluctuations in rainfall - temperature over the study area can show two periods, a dry period in summer and another wet winter. The seasonal rhythm of the basin is uni-modal. The inter-annual rainfall fluctuations shows a decreasing trend of rainfall since 1980. The deficit of rainfall through the period between years 1968-1979 and the period between years 1980-2009 is around 19%. However, the inter-annual temperatures fluctuations shows, an increasing trend of air temperatures since 1980: Temporal - Drought. Generally, the inter-annual fluctuations in rainfall decreases from south to north of the basin. Nevertheless, the inter-annual temperatures fluctuations shows that Saïs plain is warmer than the Tabular Atlas: Spatial - Drought. This could be due to the altitude gradient.

Key words: Stream Mikkes % Rainfall fluctuations % Temperature fluctuations % Temporal - Drought % Spatial -Drought % Altitude

INTRODUCTION

Inter-annual variability of Mediterranean rainfall is well established (Douguédroit [1], Bensari [2,] Cote and Legras [3], Gravel and Weisrock [4]). Most meteorological stations in the Mediterranean basin have seen a rise in air temperatures during the last three decades [5].

This study concerns about stream Mikkes, located in the north-central Morocco and covers an area of about 1600 km^2. This basin consists of different geographical area types; Prerif - Prerif Ridges in north, mountainous in South (El-Hajeb Ifrane Tabular) and Saïs plain in the centre (Fig. 1).

Equipment Basin rainfall – temperature is far from satisfactory. The lack of documentation is obvious; the long series of observations are rare. However, this paper attempts to highlight the general rainfall - temperatures fluctuations of the stream Mikkes basin and to study spatial temporal irregularities from the available data. The available data is concerned about the following stations: Moulay Idriss, El Hajra, Aîn Taoujdat, Bittit, El Hajeb, Imouzzer Kandar, Ifrane, Azrou and Fez. The location of these stations is shown in Figure 2 and on Table 1.

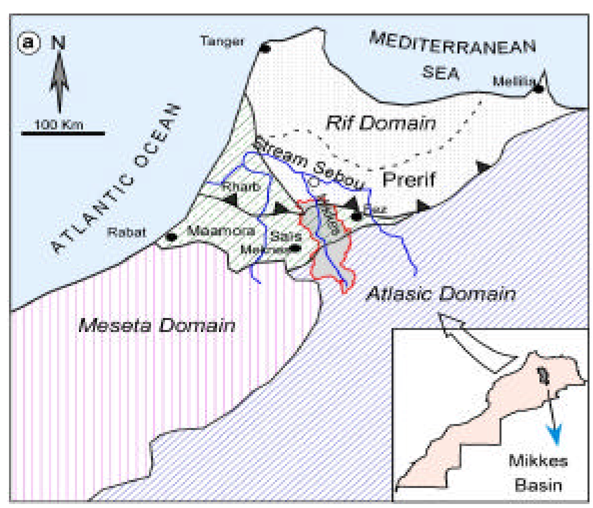

Fig. 1: Location map of the stream Mikkes basin

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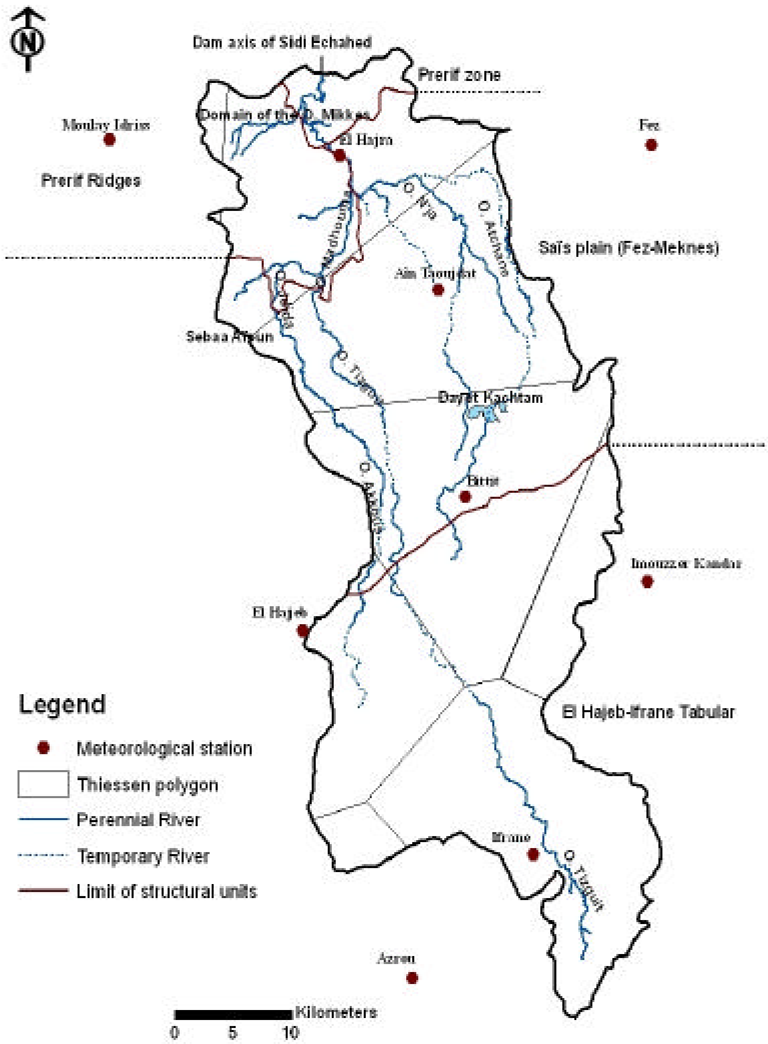

Fig. 2: Situation of the meteorological stations of the Mikkes basin

Table 1: Coordinates and average rainfall – temperature of meteorological stations.

Station Name	Altitude (m)	X (km)	Y (km)	Average rainfall (1968-2009)	Average temperature (1968-2009)
Ifrane	1635	525.5	325.9	965	12
Azrou	1508	515.077	315.836	723	-
Imouzzer Kandar	1348	535.404	348.073	605	-
El Hajeb	1050	504.596	344.103	570	-
Bittit	760	519.66	355	504	-
Moulay Idriss	550	489	384	599	17.6
Aîn Taoujdat	465	517.3	371.8	448	-
El Hajra	215	508.86	382.76	365	18.2
Fez	579	535.722	383.646	-	16.6

This work aims to determine the spatial and temporal variability of rainfall - temperatures through the period between years 1968 - 2009 in the Mikkes watershed.

Rainfall

Seasonal Fluctuations in Rainfall: For 8 stations, the regime of rainfall is Mediterranean type. The evolution of the average monthly rainfall for different stations is similar. But with much higher average rainfall at the Tabular stations than other stations which they are located inside Saïs plain (altitude gradient). The irregularities in Seasonal rainfall in the area of study has shown an extremely different values for average rainfall from one month to another, with a dry period

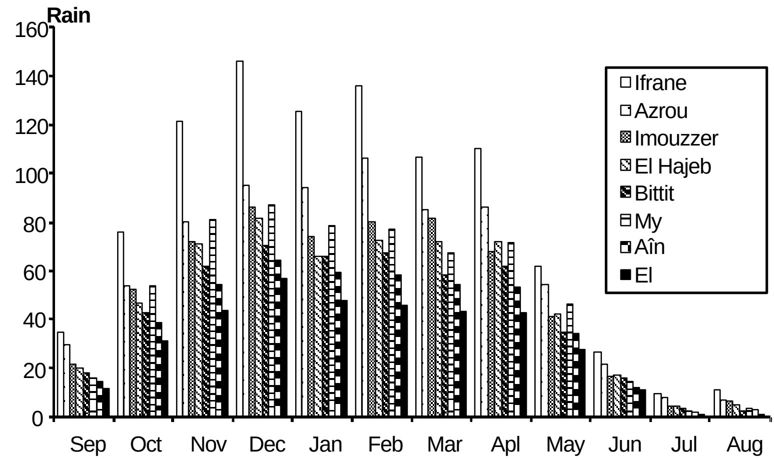

Fig. 3: Average monthly rainfall (1968-2009)

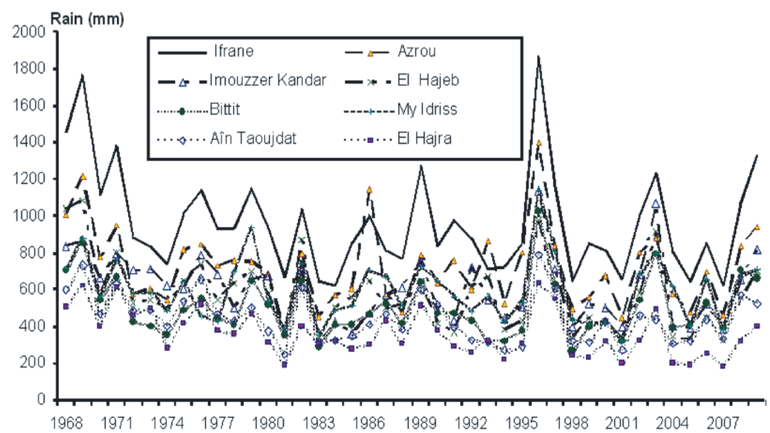

Fig. 4: Inter-annual rainfall of eight study stations (1968 - 2009)

Table 2: Average monthly rainfall (1968-2009)

Station	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Total
Ifrane	34	76	122	147	125	136	107	111	62	26	9	11	965
Azrou	30	54	80	95	94	106	85	87	55	21	8	7	723
Imouzzer Kandar	21	52	72	86	74	80	81	68	41	17	4	7	605
El Hajeb	20	47	71	82	66	73	72	72	42	17	4	5	570
Bittit	18	43	62	71	66	68	58	62	35	16	4	2	504
My Idriss	16	54	81	87	79	77	67	71	46	14	2	3	599
Aîn Taoujdat	14	39	54	64	59	58	55	54	34	12	2	3	448
El Hajra	11	32	44	57	48	46	43	43	28	11	1	1	365

that corresponds to the summer season (June, July, August), characterized by a rainfall deficit and a wet period that corresponds to other months of the year. The seasonal rhythm of the basin is uni-modal (Fig. 3).

The wet season begins from October to May, while the dry season starts from June to September. December is usually the wettest month, while July and August are the driest months. These two months, may experience highly concentrated thunderstorms and can trigger a sudden flow even in the dry valleys. March constitutes a secondary maximum. Table 2 summarizes the average data of rainfall at the eight stations for the period 1968 - 2009.

In the Tabular Atlas, the snows may fall early in October at altitudes of 2000 m. At the Ifrane city snows may fall in early December and with an average snowfall of 45 days, anyway the average snowfall varies from 20 days to more than two months [6].

Table 3: Annual rainfall variations (1968-2009)

Station	Ifrane	Azrou	Imouzzer	El Hajeb	Bittit	My Idriss	Aîn Taoujdat	El Hajra
Average rainfall	965.4	722.5	607.6	575.2	503.9	598.6	448.0	364.9
Standard deviation	288.0	217.1	186.4	195.3	161.7	171.3	132.0	124.4
Variation coefficient %	29.8	30.0	30.7	34.0	32.1	28.6	29.5	34.1

Table 4: The rushed water blade in the Mikkes watershed by the Thiessen method (1968-2009)

Station	Surface (km^2)	Precipitation (mm)	Pi * Si
Ifrane	316.21	965	305270.45
Azrou	27.36	723	19780.22
Imouzzer	88.31	605	53426.07
El Hajeb	159.23	570	90760.93
Bittit	374.93	504	188912.33
My Idriss	12.26	599	7341.37
Aîn Taoujdat	329.23	448	147490.09
El Hajra	294.47	365	107464.91
Total	1602.00	4778.81	920446.37

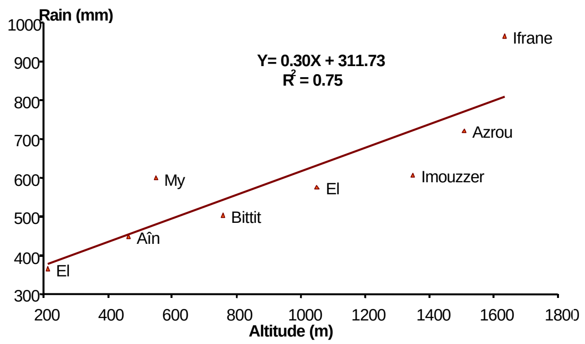

Fig. 5: Variation of rainfall with altitude (correlation coefficient R = 0.87).

Inter-Annual Fluctuations: The 42 years of monitoring rainfall at the eight stations shows that the multi-year regime is very irregular, with a coefficient of variation ranging from 28.6 to 34.1%. Figure 4 shows a clear rainfall correlation between different stations and the extreme irregularity of average rainfall from one year to another. Table 3 summarizes this data.

A comparison of the results of eight stations located in three different sectors shows that the inter-annual rainfall decreases as one moves away from the El Hajeb-Ifrane Tabular to the north of the basin. Nevertheless, at the Prerif Ridges and in particularly at Moulay Idriss station, which is characterised by higher altitude, the rainfall is important.

A diagram of altitude / precipitation is established to express the magnitude of altitude influence on rainfall. In this diagram, the altitudes are plotted on the abscissa and the precipitations which are recorded on eight stations, are plotted on the ordinate axis. The calculation of the correlation coefficient between the two parameters data gives a value of R = 0.87 which indicates a good correlation between these two variables (Fig. 5).

The value of the slope coefficient which is obtained by regression provides information on the altitudinal rainfall gradient. The mode corresponds to an increase in precipitation of 30 mm/100 m. This positive gradient shows the effects of altitude on rainfall differences.

Estimating the Rushed Water Blade: Estimating the rushed water blade in the Mikkes watershed is based on the method of Thiessen polygons. This method affects an area of influence for each of the rainfall stations. It takes into account the non-uniform distribution of pluviometer by introducing a weighting factor for each station. It also used data from rainfall stations situated in borders of the considerate area (Azrou, Imouzzer Kandar, El Hajeb and Moulay Idriss). But the topography and its effects are ignored when calculating the rushed water blade (Table 4).

$$P_{moy} = \frac{\sum_{i=1}^{i=n} P_i \times S_i}{S_T} = \frac{S_1}{S_T} \times P_1 + \frac{S_2}{S_T} \times P_2 + ... + \frac{S_n}{S_T} \times P_n$$

With:

P_i : Average annual rainfall at each station (mm)
n : Number of stations
S_i : Surface of the polygon (km^2)
S_T : Total surface of the watershed (km^2).

The rushed water table on the Mikkes watershed by the Thiessen method is about 575 mm.

Figure 6 shows the rainfall deviations compared to the rushed water table on the Mikkes watershed during the period 1968-2009. It confirms the irregular rainfall and highlights a significant decline in water inputs

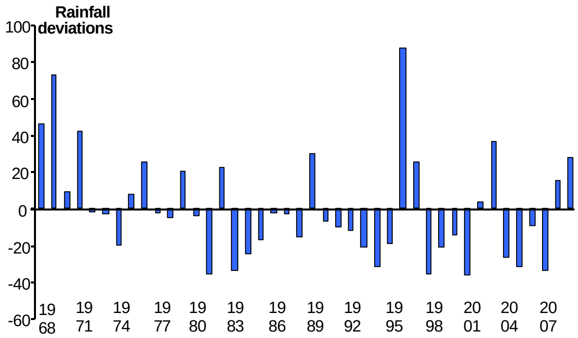

Fig. 6: Rainfall deviations compared to the rushed water table on the Mikkes watershed during the period 1968-2009

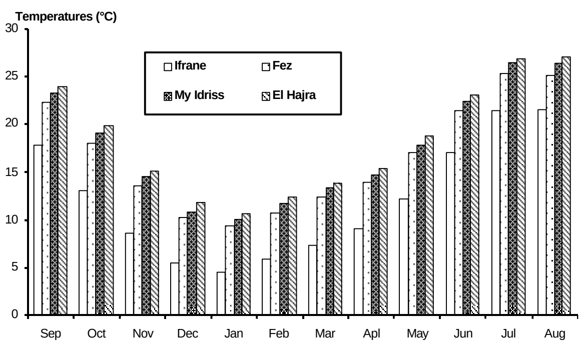

Fig. 7: Average monthly temperatures (1968 - 2009)

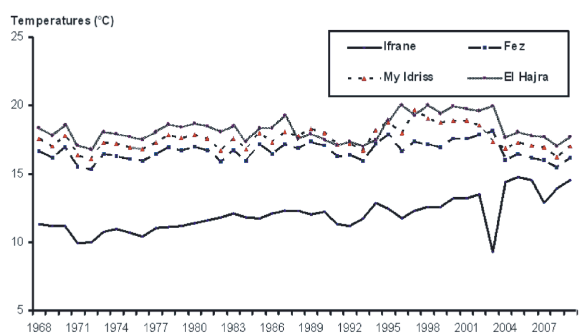

Fig. 8: Average annual temperatures (1968 - 2009)

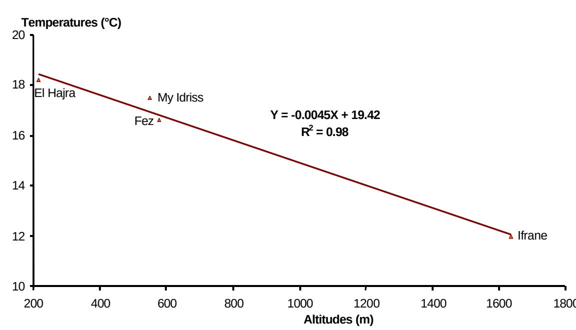

Fig. 9: Variation of temperature with altitude (correlation coefficient R = -0.99).

since 1981. This graph shows that before the 80's, the deficit years were few. Nevertheless, the years of excess water were frequents. In recent decades, the years of drought have become recurrent; except the following years: 1982, 1989, 1996, 1997, 2003, 2008 and 2009 which experienced heavy rains.

Since 1968, four years had recorded excess of water with a percent over 40% compared on average water table. This is in ascending order of importance of the year: 1971 (42%), 1968 (46%), 1969 (73%) and 1996 (88%). However, three years have been remarkably dry, which are recording a deficit of 36% on average water table. These are the years: 1981, 1998 and 2001.

The deficit of rainfall between the period 1968-1979 and the 1980-2009 period is around 19%.

Temperatures

Seasonal Fluctuations in Temperature: The fluctuation in average monthly temperatures of the four stations (Ifrane, Fez, My Idriss and El Hajra) during the period 1968-2009 is shown in Figure 7. The temperature evolution is similar from one station to another. However, a lower temperatures are observed in the Ifrane station in all months, followed by the Fez station with higher temperature degrees, then My Idriss station and then El Hajra station. Actually, monthly temperatures data for all stations follow the same pattern and they are all affected by altitude.

At Ifrane station, the average monthly temperature range goes from a maximum of 21.5°C in August and a minimum of 4.5°C in January. At Fez station, the average monthly temperature varies from 25.3°C in July to 9.3°C in January. At My Idriss station, the temperature range goes from 26.5°C in July to 10.1°C in January. At El Hajra station, the average monthly temperature fluctuates from a low of 10.6°C in January and a maximum of 27.1°C in August.

The hot season extends from May to October; where monthly temperatures are above annual average. While the cold season extends from November to April. The maximum temperature is reached in July and August with an average of 25°C. While the minimum is reached in January, with an average of about 8.6°C. This divided the year into two thermal seasons, which is highlighted by a determination of wet and dry months, which has some consequences on the hydrological – hydro-geological context of basin. In fact, the large monthly oscillations during the coldest months are accompanied by significant events, such as drop in temperature and rainfall events which generates floods and it directly

Table 5: Temperature variations between the period 1968-1979 and 1980-2009 in the four stations Mikkes Basin.

	Ifrane	Fez	My Idriss	El Hajra	Average T (°C)
Temperatures (1968-1979)	10.81	16.29	17.14	17.90	15.53
Temperatures 1980-2009	12.48	16.77	17.75	18.38	16.34
Difference	1.67	0.49	0.60	0.48	0.81

affects the stream flow. Similarly, the effect of the hot season is not without consequences. Therefore, the stagnation of air mass associated with anticyclonic conditions provokes a rainfall deficit and high evapotranspiration. Periods of low water levels are long; thus, drying up of a stream reach [7].

Inter-Annual Fluctuations in Temperature: Inter-annual variability of temperatures appears clearly with a coefficient of variation ranging from 4 (Fez station) to 10.7°C (Ifrane station). Extreme values of temperature are between 9.3 and 14.8°C at Ifrane station which its average annual temperature is 12°C (1968-2009). In Fez station, the annual temperatures varies between 15.3 and 18.2°C, the average annual temperature is 16.6°C (1968-2009). These values are between 16.1 and 19.7°C at the station My Idriss where the average annual temperature is 17.5°C (1968-2009). While in the El Hajra station, the extreme values varies from 16.8 and 20°C and the annual average value is about 18.2°C during the period 1968-2009 (Fig. 8).

The general trend is the resurgence of years at high temperature during the period between 1980-2009. This evolution is related to the hypothetical global warming due to greenhouse effect. The uncertainties of global change, highlighted by many researchers (Douguédroit [8]; Lamarre and Pagney [9]; Delannoy [10]; Vigneau [11]; El Jihad [12]), are even greater when one goes down to local scale. It is difficult to deduce from a chronic restricted of temperatures measures (42 years) a local climate evolution, which is also not excluded.

A correlation diagram altitude/temperature was performed for the Mikkes basin. This brought the altitude of the stations on abscissa and the values of the inter-annual average temperatures on ordinate axis.

The linear correlation coefficient R is equal to -0.99; it is very close to -1, indicating a good inverse relationship between temperature and altitude (Fig. 9).

The value of the slope coefficient obtained by regression provides information about the altitudinal temperature gradient. The mode is corresponding to a temperature decrease with a value of about 0.45°C/100 m. This gradient shows the effects of altitude on temperature variations.

To visualize the spatial - temporal drought experienced by the Mikkes basin. A temperature comparison was performed for the period between1968-1979 and the period between 1980-2009. The result is shown in Table 5.

At Ifrane station, the average annual temperature during the period 1968-1979 is 10.81°C, it increased during the period (1980-2009) to reach 12.48°C.

At Fez station, the average annual temperature during the period between 1968-1979 is 16.29°C; it increased during the period (1980-2009) to reach 16.77°C.

At My Idriss station, the average annual temperature during the period 1968-1979 is 17.14°C, it increased during the period (1980-2009) reaching 17.75°C.

At El Hajra station, average annual temperature during the period 1968-1979 is 17.90°C, it increased during the period (1980-2009) to reach 18.38°C.

The temperature increase could be the result of climate change observed in Morocco and specifically in the Mikkes basin (Alibou [13]). The average annual temperature at El Hajra station, during the period 1968-1979, is 17.90°C and it is 10.81°C at Ifrane station. It is obvious, that difference between the temperature recorded in the Saïs plain (El Hajra station) and that observed in the Tabular Atlas; Ifrane station (1968-1979) is large; it is 9.7°C. This could be explained the influence of altitude to the intra-annual drought distribution.

CONCLUSION

Tabular station has a greater average rainfall than any other station in Saïs plain, while the Mikkes stations has similar evolution of monthly average rainfall. Mikkes basin is considered as uni-modal according to its seasonal rhythm. The study has shown irregularity in seasonal average rainfall with different values from month to another and through dry and wet periods.

The regime's multi-year rainfall in the Mikkes basin is irregular. Generally, the inter-annual rainfall decreases when one moves away from the El Hajeb-Ifrane Tabular to the north of the basin and therefore the effects of altitude on rainfall.

The rushed water table by the Thiessen method is about 575 mm. The deficit of rainfall for the years between 1968-1979 and the years between 1980-2009 is approximately 19%.

The evolution of average monthly temperatures between stations is similar. Nevertheless, with high low temperatures in the Tabular Atlas; Ifrane station (altitude gradient). Seasonal temperatures irregularities in the study area show a highly variable temperature regime one month to another, with a dry period and other wet.

The multi-year regime of temperature in the Mikkes basin is irregular. The general trend is the resurgence of years at high temperature during the period 1980-2009; temporal drought. Generally, inter-annual temperature increases from the Tabular Atlas to the north basin. The temperature difference recorded between the Saïs plain and that observed in the Tabular Atlas (1968-1979) is large, it is 7.09°C; spatial drought. The altitude affects the spatial distribution of intra-annual droughts.

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