



## Estimation of Real Seasons in a Semi-Arid Region, Ghardaia, Case Study

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<https://doi.org/10.18280/ijstdp.160602>

### ABSTRACT

**Received:** 4 January 2021

**Accepted:** 1 September 2021

#### Keywords:

*climate, seasons, RET screen, hygrothermal comfort, MCP and DJC*

For any new applicable and profitable investment in the thermal field of any region, we aim to eliminate or renovate conventional heating and air conditioning systems with new systems, which will work with new energies or renewable. First, you need to know the climate characteristics of these regions. In this study, we determine the diagnosis of the climate of arid and semi-arid regions, taking Ghardaia as an example. These concerns air conditioning, heating, cold, ventilation, thermal water, for all this, we use the data from the two weather stations located on the Terrace of our research unit applied to renewable energies (URAER), Ghardaia, for the last five years (2012-2016), to calculate the day degrees heating and air conditioning (DJC and DJF) and the obtained results have been compared with the RET Screen motor from (1980\_2006). Our approach allows us to discover a simple graphic method to characterize the seasons of Ghardaia; applicable for any region around the world. In addition, it allows the real determination of the hygrothermal comfort of the region as well as the thermal characteristics of the MCPs adaptable to the Saharan climate.

## 1. INTRODUCTION

Throughout The climate of our planet is based on seasons, which are classified into two major categories, namely; astronomical and real seasons. Generally, the astronomical seasons are known by their spring and autumn equinoxes' seasons, whereas summer and winter are the solstice's seasons. The first category practically keeps the same behavior on global scale [1]. However, the second category varies from one region to another, due to several parameters [2]. The determination of inter-season periods is thermally ideal and passively comfortable and based on different parameters [3]; among them:

- Start and end of the device operation; Such as heating and air conditioning [3].
- Heating Day (DJC) and Day Air Conditioning (DJF) degrees; are as small as possible (weak) [4].
- Internal hygro-thermal comfort; are generally insured within the comfort intervals by temperature ranges ( $18 < T_c < 28$ ,  $25 < H_c < 80\%$ ) [4].
- External temperatures are nexus the internal temperatures (The temperature ranges between the outside and inside of the building is low).
- Wind speeds.
- Atmospheric pressure, sunshine and precipitation.

So it can be said that the challenge in these periods is to avoid as possible the use of heating and air-conditioning systems. In other hand, the natural hygro-thermal comfort

should be ensured (the inertia of the housing and the natural ventilation), based on the sensitive storage which is difficult. This is due to the influence of several indices related to human beings or to the buildings themselves [5], such as human metabolism (age, sex, fatigue, etc.), ambient temperature ( $T_a$ ), the mean temperatures radiated from the walls ( $T_p$ ) relative air humidity ( $H_r$ ), air velocity, orientation of the building and other Different materials used, insulation, etc.). Additionally, the internal thermal imbalance and all the known problems can be partially solved by applying new techniques and approaches. Accordingly, it can be cited the intelligent materials called phase change materials (PCM) based on the latent storage principle, whose their melting temperatures are closer to the desired comfort temperature (between  $18^\circ\text{C}$  and  $27^\circ\text{C}$ ). The storage and discharge of these materials are based on the endothermic-exothermic phenomena whose shape variation is sinusoidal (above and below these melting temperatures).

Several researches adopted the selection and integration of this new material in summer. They focused on the integration based on the use of phase change materials in the building structure. Therefore, its choice is reduced to a single melting temperature in the comfort interval, between  $17^\circ\text{C}$  and  $30^\circ\text{C}$ . Accordingly, a study has been carried out within this field in Ghardaia region by Stojanovi et al. [6]. These essential thermal problems related to buildings, caused many of the social hazards and social problems such as: the carbon monoxide emission ( $\text{CO}_2$ ) which causes environmental impacts: In

Algeria; for example;

The number of people who died between 1 January and 09 February 2017, was 49 people, due to the carbon monoxide emitted by the different heating systems at the national scale [6], High heating and air conditioning bills, Greenhouse gas emissions (the increase in CO<sub>2</sub> in the planet), thermal imbalance in housing, etc.

The climate is variable over the world regions and in the same country due to the radical change, the geographical localization ... etc.). In the Algerian case, the climate varies from north to south and divided into seven main climatic zones (A, B, B, C, D1, D2, D3), zone has a different weather conditions. Thus, our current study is based on Ghardaïa region characteristics, which presents a hard climate, regarding its important situation in the southern part of Algeria, which belongs to the climatic zone D1. The known weather of this city is a cold winter within three months (December, January and February) and a dry very hot summer within a period of five months (May, June, July, August and September). In addition to the spring disturbances, caused by sandy storms between April and March, however, the fall season is generally the most stable weather within period (October and November). This medium weather influences the energy expenditure of the summer period within the months [May, June, July, August and September]. In other times, it constitutes the more rate with (3/2); including the months of winter period [December, January and February]. Reference to the work of [7], about 16893.4 KWH in summer 2014 and about 12738 KWH in winter of the years [2013-2014] have been recorded, respectively. This study yielded energy expenditure of 28% for the winter, 13% for the spring, 42% for the summer and 17% for the fall. In order to raise these problems mentioned above, our work based on a new idea, and on the integration of two phase change materials, at different melting temperatures (MCPTf1 and MCPTf2), within the comfort intervals [18°C, 27°C]. The used values are for the winter season between 18°C and 22°C and for the other for the summer season between 24°C and 28°C.

The main objectives of this project are the radical elimination of active heating and cooling during the inter-season periods to will make the most of the equinoxes (autumn and spring) to ensure hygrothermal comfort.

Because the difference between the mean (amplitude) temperatures of the night and day (daytime and night) of the equinoxes is not great, they remain acceptable [between -5 and +5]. But the amplitudes of the solstices remain large over all the Saharan regions and over the high plateaus of Algeria (between 0 and 30) [8]. Unfortunately, we are faced with the thermal failure of the two solstices and all of them in the summer period. The technical aspect of this new idea will allow us to delay the re-entry of the thermally critical seasons (winter and summer) and accelerate it out of its periods. A time prolongation of the real intervals of the two equinoxes takes place by a precise selection and the specific integration of the two intelligent materials (MCPs). For the proper functioning of the storage and the discharge of the MCPs; the use of its MCPs will reduce the energy consumption related to heating, air conditioning and diminution of greenhouse gases. These materials will delay and dampen peak temperatures in the heat wave periods, in a dysphasic manner and the distance of time from the devices will affect the improvement of the social and economic Tangible reality with these integration techniques.

Our current work consists of a first kind study, which involves the actual use and study of the two MCPs in the

building structure. First, it will consist of a site selection, a construction of a large meteorological database of two stations [ENERCO (Series 400 and 500), German] Thus, the obtained data were compared to the climatological data of the RET Screen engines of [1980-2006], as well as data acquired from the National Weather Office (ONM) of Ghardaïa. Accordingly, the heating day (DJC) and the day of air conditioning (DJF) have been calculated. In the goal to determine exactly the actual thermal seasons and to make simulated calculus, moreover, the intervals days between the seasons were selected and the real socio-economic impact of the MCPs integration in the multizone building tissue, in the region of Ghardaïa, is deduced.

## 2. AREA STUDY DESCRIPTION

The our study was conducted on a habitat located in a functional housing city of research applied unit of renewable energies (URAER) at Ghardaïa with a living area of 71.3 m<sup>2</sup>, of 66 m<sup>2</sup> actual surface to heated and / or cooled, the height of the walls is 2.8 m (Figure 1). The windows are simple, clear glazing with a thermal transmittance which equals  $U = 5.91 \text{ W} / (\text{m}^2 \cdot \text{K})$ . The doors are wooden and 2 cm thick:  $\lambda = 0.14 \text{ W m}^{-1} \text{ K}^{-1}$ ,  $\rho = 500 \text{ kg} \cdot \text{m}^{-3}$  and  $C_p = 2500 \text{ J} \cdot \text{kg}^{-1} \cdot \text{K}^{-1}$ . ( $\lambda$ ,  $\rho$  and  $C_p$ , respectively the thermal conductivity, the density and the specific heat) [2].

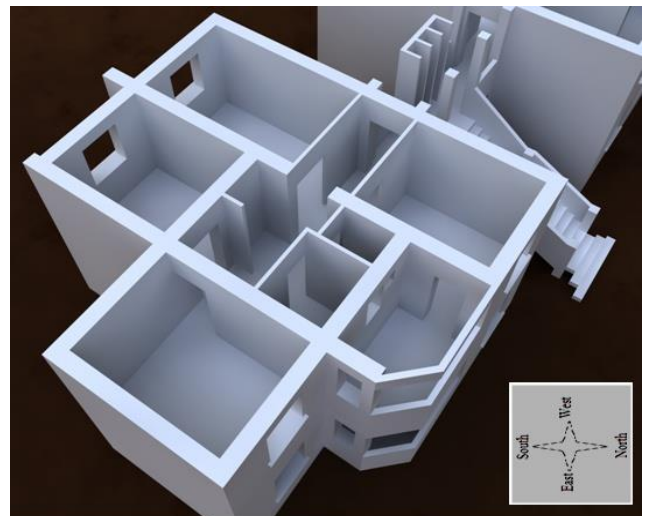


Figure 1. 3D plan of the chosen house

## 3. MATERIAL AND METHOD

The Wireless Weather Station with Touch WS2-550: is used to record, process and display real internal data for a 2016 year of accommodation studied at the level of our URAER city. It is a very reliable and efficient station, equipped with a combined weather sensor (thermo-hygrometer, rain gauge, and anemometer).

For the outside date collection an efficient specific metrological station has been used to, measure several parameters such as temperatures, humidity, wind speed, pressure, and solar radiation (Figure 2).

The station Operates with 10 min and an accuracy of 0.005 (°C).



Figure 2. URAER Ghardaïa weather station

According to the diagnosis of [8].

$$T_n = 9.22 + 0.48T_{int} + 0.14T_{ext} \quad (1)$$

This is the new standard 55-200432, which he used by Khelifi et al. [9]. The choice of the building's comfort domain, linked to the impacts of several parameters, cited above, and others which are grouped in the following two tables (Table 1 and Table 2) [10].

Table 1. Contact temperature between the human body and some materials [10]

Materials	contact temperature
steel	$\theta_C = 2.1 + 0.93 \theta$
concrete	$\theta_C = 10.6 + 0.65 \theta$
stone	$\theta_C = 11.9 + 0.18 \theta$
Wood	$\theta_C = 19.4 + 0.35 \theta$
carpet	$\theta_C = 27.5 + 0.08 \theta$

$\theta_C$ : the contact temperature between the human body and some materials;  $\theta$  is the initial temperature of the material; eg;  $\theta$  stone = 20°C,  $\theta$  concrete = 5°C

### The choice of the comfort range [19°C-30°C]:

1. **Comfort temperature:** Several researchers are working on the determination of thermal comfort limits on buildings;

Table 2. Operational temperatures for summer and / or winter comfort [11]

Hab. H (clo)	Temp. oper. to (°C)	PMV according to the relative air velocity (m/s)									
		Activity level M = 70W/m <sup>2</sup>									
		<0.10	0.10	0.15	0.20	0.30	0.40	0.50	1.00	1.50	
0.5 Summer	18	-2.01	-2.01	-2.17	-2.38	-2.70	-	-	-	-	-
	20	-1.41	-1.41	-1.58	-1.76	-2.04	-2.25	-2.42	-	-	-
	22	-0.79	-0.79	-0.97	-1.13	-1.36	-1.54	-1.69	-2.17	-2.46	-
	24	-0.17	-0.20	-0.36	-0.48	-0.68	-0.83	-0.95	-1.35	-1.59	-
	26	0.44	0.39	0.26	0.16	-0.01	-0.11	-0.21	-0.52	-0.71	-
	28	1.05	0.96	0.88	0.81	0.070	0.61	0.54	-0.31	-0.16	-
	30	1.64	1.57	1.51	1.46	1.39	1.33	1.29	1.14	1.04	-
1.0 Winter	16										
	18	-0.75	-0.75	-0.88	-0.98	-1.13	-1.24	-1.33	-1.59	-1.75	-
	20	-0.32	-0.33	-0.045	-0.054	-0.67	-0.76	-0.83	-1.07	-1.20	-
	22	0.13	0.10	0.00	-0.07	-0.18	-0.26	-0.32	-0.52	-0.64	-
	24	0.58	0.54	0.46	0.40	0.31	0.24	0.19	0.02	-0.07	-
	26	1.03	0.98	0.91	0.86	0.79	0.74	0.70	0.57	0.50	-
	28	1.47	1.42	1.37	1.34	1.28	1.24	1.21	1.12	1.06	-
30	1.91	1.86	1.83	1.81	1.78	1.75	1.73	1.67	1.63	-	

## 4. DETERMINATION OF PARAMETERS

### 4.1 Temperatures, humidity and solar evolution in deferent season

We gather the real data of four separable periods between the seasons, which start from 2012 until 2016, our choices start with the meteorological data of the station ENERCO during the five years, for temperatures, external humidities, wind speeds, atmospheric pressures and global solar radiation. Periods are: [February 14-March 14], [May 16-June 14], [August 16-September 14] and [November 15-December 14] (Figures 3-26).

- **Period 01; [for February 14, 2012 to March 14, 2016]:**

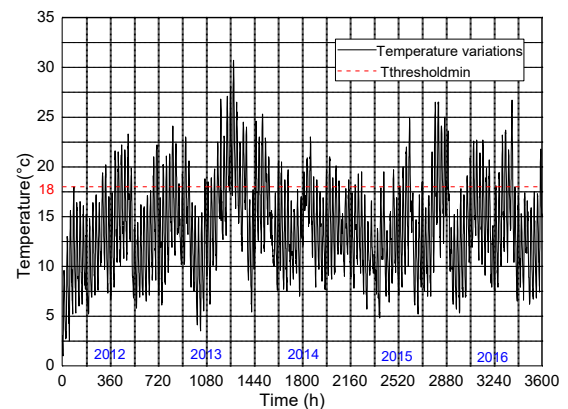
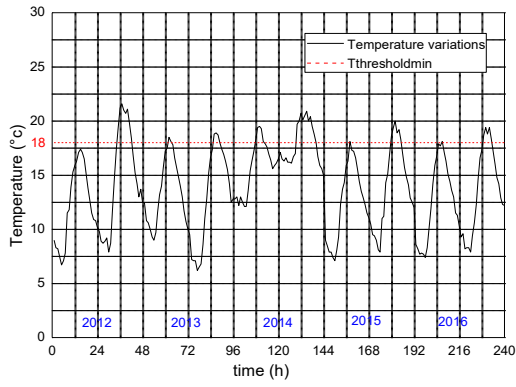
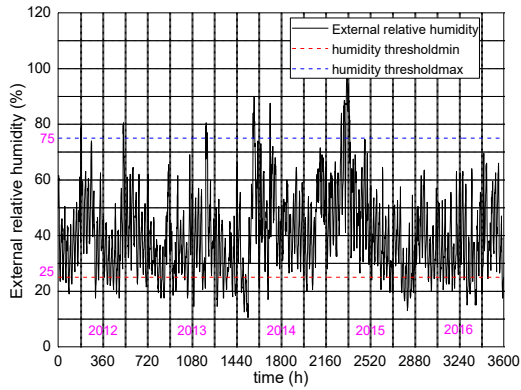


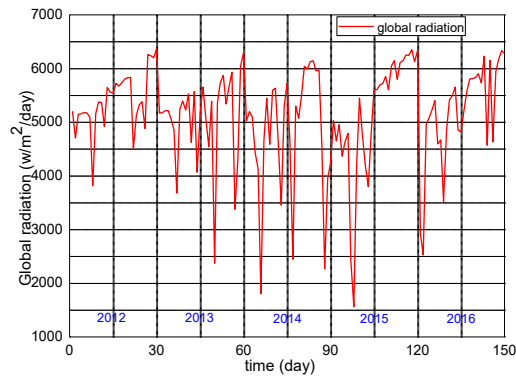
Figure 3. Outside temperature during the first period in 2012 to 2016



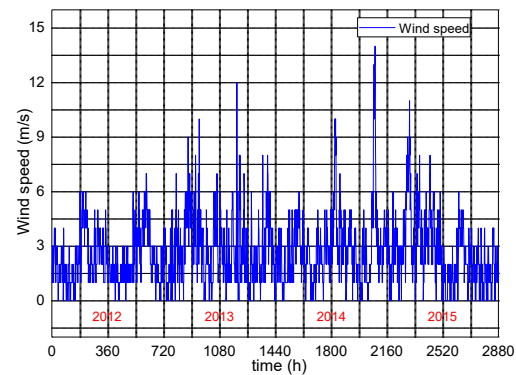
**Figure 4.** Outside temperature evolutions during the two days 01/03 et 02/03, of the first period



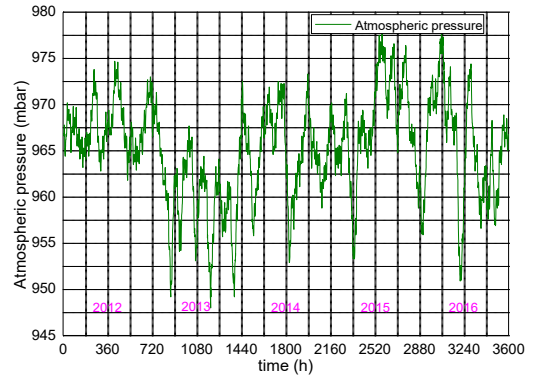
**Figure 5.** Outside humidity during the first period in 2012 to 2016



**Figure 6.** Solar radiations evolution during the first period in 2012 to 2016

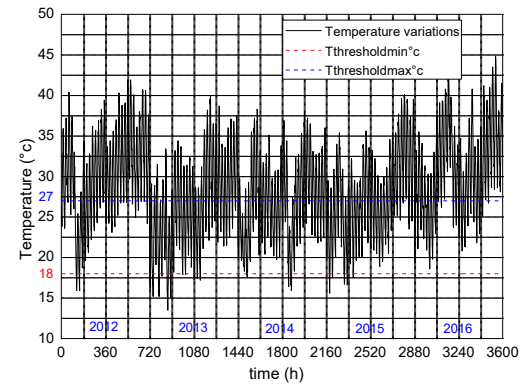


**Figure 7.** Outside wind speed variation during the first period 1 in 2012 to 2016

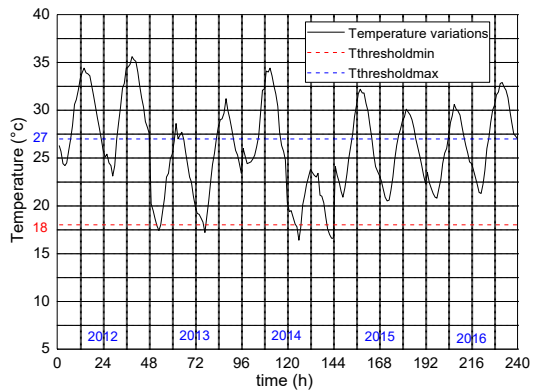


**Figure 8.** Pressure variations during the 2012 to 2016

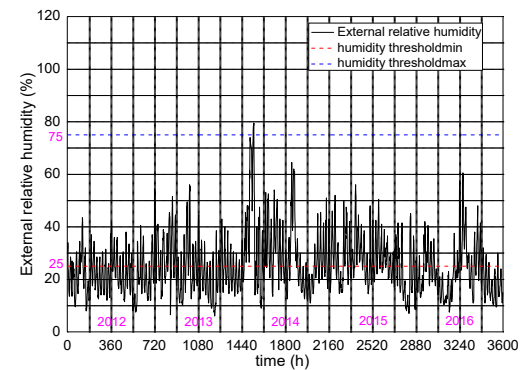
○ **Period 02; [for May 16, 2012- to June 14, 2016]:**



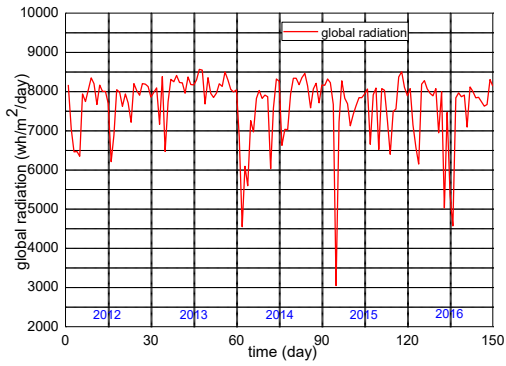
**Figure 9.** Outside temperatures evolutions during the second period for 2012 to 2016



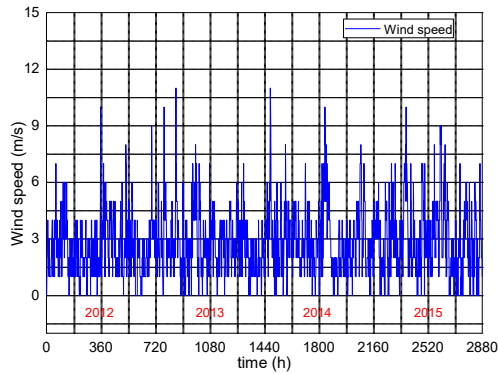
**Figure 10.** Temperatures evolutions during the 01/06 and 02/06, for the second period



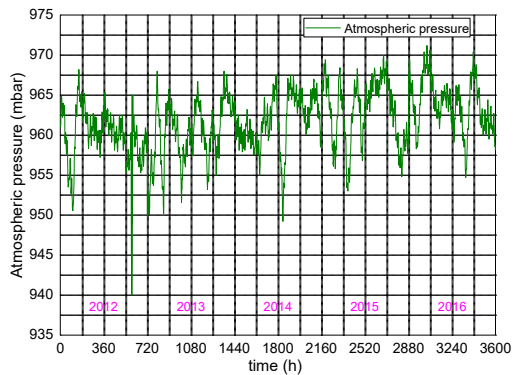
**Figure 11.** The humidity variation during the second period of 2012 to 2016



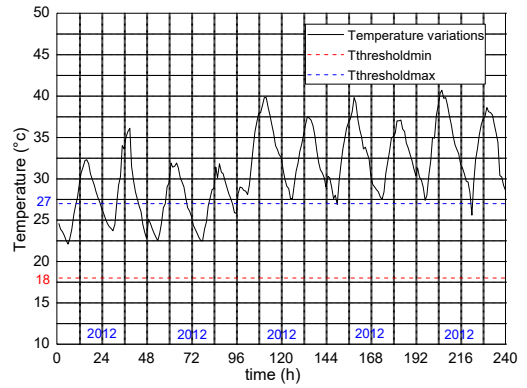
**Figure 12.** Solar radiation during the second period for 2012 to 2016



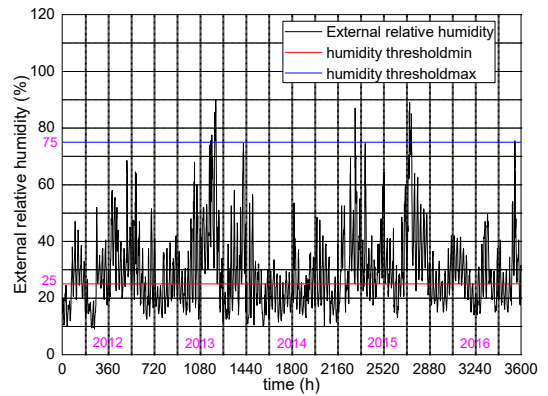
**Figure 13.** Wind speed variation during the second period of 2012 to 2016



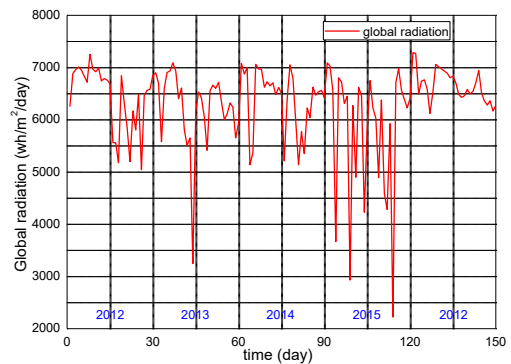
**Figure 14.** Pressure variation during the second period of 2012 to 2016



**Figure 16.** Temperature evolutions during 01/09 et 02/09, for the 3<sup>rd</sup> of 2012 to 2016

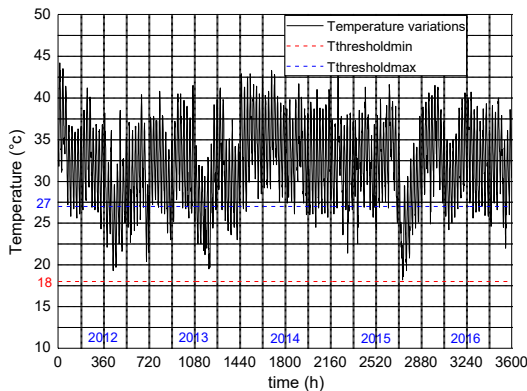


**Figure 17.** Humidity variations des huminites during the 3<sup>rd</sup> of 2012 to 2016

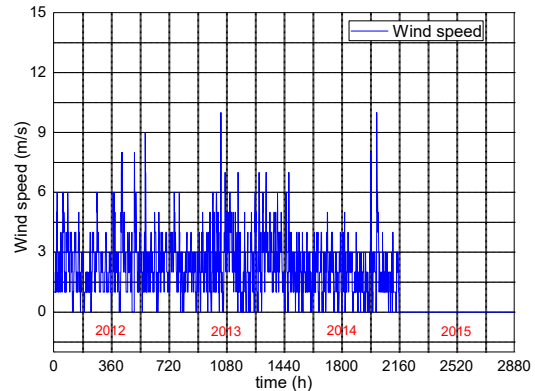


**Figure 18.** Solar radiations during the 3<sup>rd</sup> of 2012 to 2016

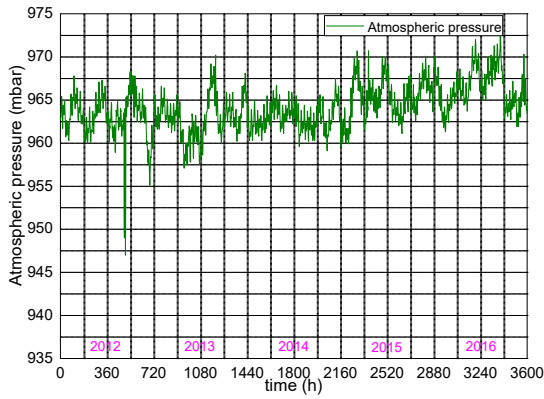
○ **Period 03; [for August 16, 2012 to September 14, 2016]:**



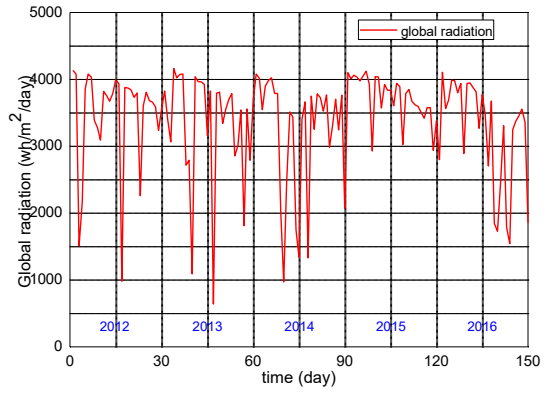
**Figure 15.** Temperature evolution during the 3<sup>rd</sup> of 2012 to 2016



**Figure 19.** Wind speed variation during the 3<sup>rd</sup> of 2012 to 2016

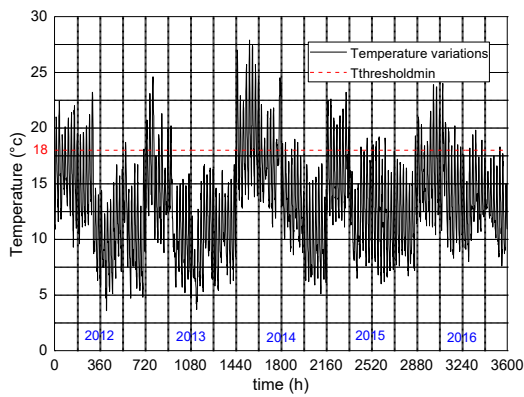


**Figure 20.** Pressure variation during the 3<sup>rd</sup> of 2012 to 2016

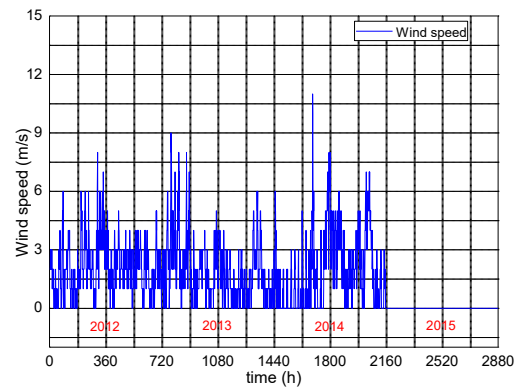


**Figure 24.** Solar radiation during the 4<sup>th</sup> period of 2012 to 2016

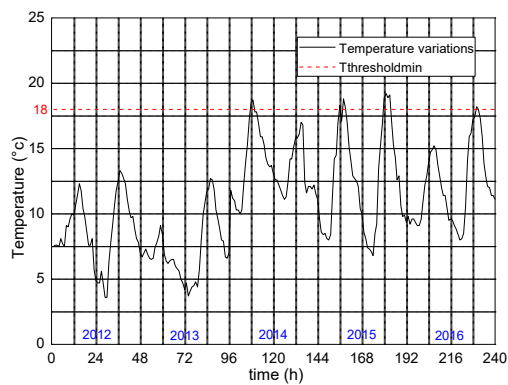
○ **Period 04; [for November 16, 2012 to December 14, 2016]:**



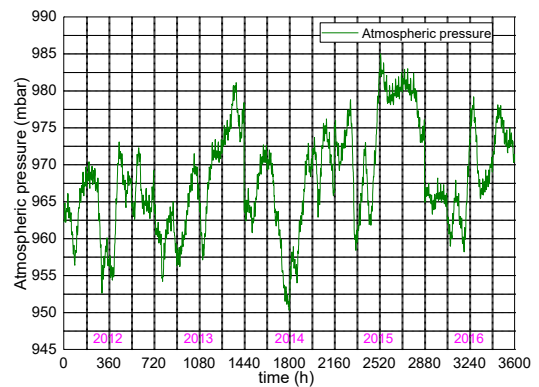
**Figure 21.** Temperature evolution des during the 4<sup>th</sup> period of 2012 to 2016



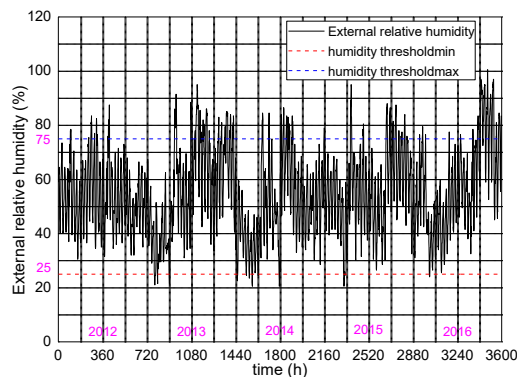
**Figure 25.** Wind speed variations during the 4<sup>th</sup> period of 2012 to 2016



**Figure 22.** Temperature evolution during 01/12 et 02/1 for the 4<sup>th</sup> period of 2012 to 2016



**Figure 26.** Pressure variation during the 4<sup>th</sup> period of 2012 to 2016



**Figure 23.** The humidity variations during the 4<sup>th</sup> period of 2012 to 2016

## 5. CALCULATION OF THE DJC AND DJF

For the calculation of the day Degrees; either for heating (DJC) or for air conditioning (DJF), we have several methods that do this, among the most used; the real method what I call " the professional energy method " (conforms to the regulatory Costic method for the heating and air conditioning operating markets to be used for monitoring) and the "Weather" method with simple calculation, to be used by the RET Screen motor [08].

The importance of calculating the degree-day is to allow estimating the expenditure of energy consumption linked to the thermal (heating and air conditioning) of the buildings.

Therefore, it is the evaluation of the harshness of the climate from one year to another and from one region to another (to compare buildings located in different climatic zones and to compare years of heating between them, p .ex. following investments). The Degree Day for any chosen site is a value representative of the difference between the temperature of a given day and a preset temperature threshold.

The Degree Day for any chosen site is a value representative of the difference between the temperature of a given day and a preset temperature threshold [12-14].

Tmin: Minimum temperature for D-day measured at 2 meters from the ground under shelter and recorded between D-1 (the day before) at 6 p.m. and D at 6 p.m. UTC.

Tmax: Maximum temperature on day D measured at 2 meters from the ground under shelter and recorded between D at 6 a.m. and J+1 (the next day) à 06h UTC.  $T_{moy} = \frac{T_{min} + T_{max}}{2}$ , average temperature of the day.

Tcs: Set point temperature or selected reference temperature threshold.

For our study: Tcs1 = 18°C and Tcs2 = 27°C.

In our calculation, applied the following two methods:

• **Weather method:**

$$If (T_{cs1} < T_{moy}), DJC = 0; If (T_{cs1} > T_{moy}), \dots\dots\dots DJC = T_{cs1} - T_{moy} \quad (2)$$

• **Professional energy method:**

For the start and end of the heating period:

$$DJC = (T_c - T_{min}) * \left( \frac{0.08 + 0.42 * (T_c - T_{min})}{(T_{max} - T_{min})} \right) \quad (3)$$

For the start and end of the air conditioning period:

$$DJF = (T_{max} - T_c) * (0.08 + 0.42 * (T_{max} - T_c) / (T_{max} - T_{min})) \quad (4)$$

**Table 3.** Heating day degrees using the actual method, weather method compared with data from the average RET screen motor

Degree Day for Heating (DJC)	Period 1 [February -March]					Period [November-December]				
	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
M*: DJC, Real	235	105	32	81	57	195	180	57	88	113
M*: DJC «Weather»	193	103	15	81	37	156	167	56	75	107
RET Screen average data from [1980_2005], 18°C	<b>101.50</b>					<b>138.00</b>				
<b>Absolute difference</b>	42	02	17	00	20	39	13	01	13	06
Average DJC	P1	<b>102</b>			<b>86</b>	P4	<b>127</b>			<b>130</b>

**Table 4.** Air conditioning day degrees using the actual method, weather method compared with data from the 26-year-old RET screen motor

Day Degrees for air conditioning (DJF)	Period 2 [May-June]					Period 3 [September-October]				
	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
M*: DJF, Real	144	28	53	48	75	193	107	252	231	220
M*: DJF «Weather »	137	76	50	83	58	184	98	240	231	221
RETS screen data from [1980-2005], 27°C	<b>82.5</b>					<b>103</b>				
<b>Absolute Difference</b>	07	48	03	35	17	09	09	12	00	01
Average DJF	P2	<b>70</b>			<b>81</b>	P3	<b>201</b>			<b>195</b>

Note that the results in the two Tables 3 and 4 are comparable with each other and coincide with that of RETS screen, the differences either less or more because of the influence of global warming which has become a reality in Algeria [15-17].

**6. DETERMINATION OF THE REAL SEASONS**

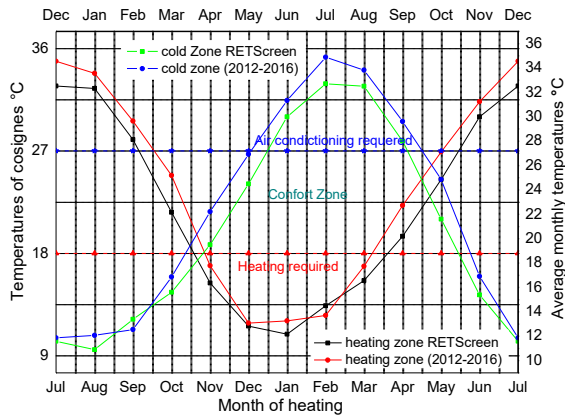
After calculating the Heating and Air Conditioning Day Degrees (DJC and DJF) for the Ghardaïa site, of five years [2012 to 2016], from the base temperatures of 18°C and 27°C; by the two real and weather methods, compared these results with that of the RETS screen data for 26 years (1981-2006). I have plotted all these data in representative graph salt, call the integral diagram. This graph gives with a clear way, the beginning and the end of each season [18, 19].

Figure 27, giving clearly and really by the methods [DJC

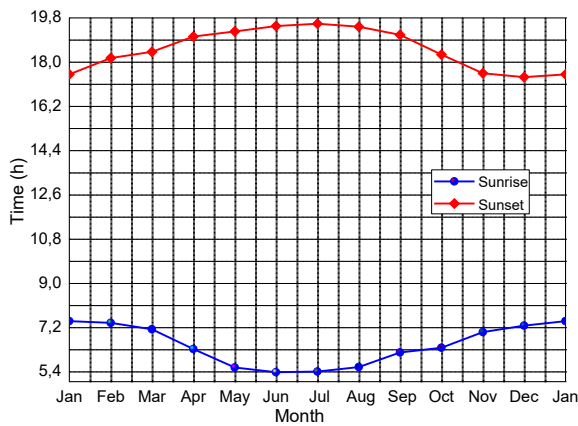
and DJF] the beginning and the end; cold seasons (late October to early March), overheating seasons (early May to mid-September) and comfort seasons; for spring (early March until the end of April) and for fall (mid-September until the end of October). These results for the years (2012-2016) and well coincide for comparison with that of RETS screen since 1960; from the Ghardaïa region.

Noting that the return of the critical seasons in recent years (summer and winter) disrupted, advanced and their interval widened and grow has the impact of climate change that hit the whole world and has become a reality even for our country Algeria [20].

According to this diagram (Figure 28), can easily determine by the integrate method consumption either in heating or in air conditioning and the comfort zone. This then determines what objective is looking for (elimination or reduction of the use of heating and air conditioning), that it incorporates material and that it invests in it.



**Figure 27.** Real determination of heating, comfort zone [18°C: 27°C:] and air conditioning zone in Ghardaïa according to RETS screen data since 1960

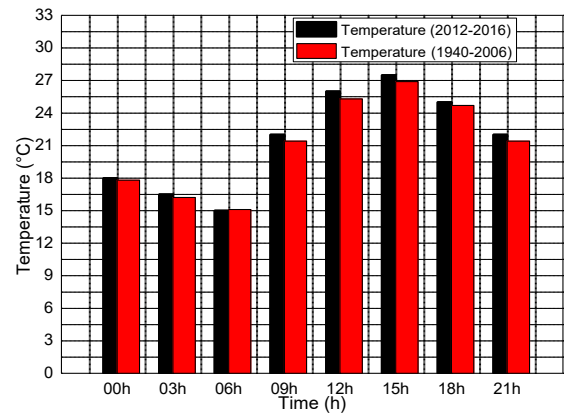


**Figure 28.** The annual (sunrise and sunset) of the sun, as well as the length of the day during the year in Ghardaïa [09]

## 7. TEMPERATURE EVOLUTION

In Figure 29, we note that the evolution of average temperatures at synoptic hours of Ghardaïa during the five years of our study (2012-2016) are increasing compared to

NASA data from (1940-2006), due to global warming.



**Figure 29.** Evolution of average temperatures at synoptic (average temperature of the Ghardaïa region) hours of Ghardaïa (2012-2016) compared with the Ret screen (1940-2006)

## 8. DETERMINATION OF SEASON INTERVALS

The remarks from Tables 5 and 6; giving a clear and reliable vision of the possibility of delaying the entry of the two critical seasons thermally (summer and winter) and also the acceleration of coming out of winter by innovative techniques (for example: MCPs).

Since the increase temperature variations and especially humidity; you approach neighborhoods of comfort intervals; sinusoidally (above and below these comfort temperatures and humidities).

However, these difficult ones accelerated the exit from the heat waves of summer. Other observations on the average temperatures measured are comparable with those of the RETS screen motors and the measurements of the German station, same remarks for humidities. Therefore, the problem of comfort on the humidity side does not pose a problem for human beings because the majority of the variations of the latter located at the comfort range [20%-80%].

**Table 5.** Changes in actual temperatures in the seasons' limit intervals; of Ghardaïa site, during the last five years of (2012 until 2016), compared with those of the German Precision Station of (10 minutes) and with RetS screen data of (1980-2006)

Number of hours		2012	2013	2014	2015	2016	Totals
<b>Period 1</b> [14/02_15/03]	T<18°C	640	502	588	611	584	2925
	T>18°C	79	214	129	106	126	654
	T>27°C	0	11	0	0	0	11
	<b>18°C &lt; T &lt; 27°C</b>	<b>79</b>	<b>203</b>	<b>129</b>	<b>106</b>	<b>126</b>	<b>643</b>
T <sub>avr</sub> RETS=14,5	T=18°C	1	4	3	3	10	21
	T=27°C	0	0	0	0	0	0
T <sub>avr</sub> S, A= 15,07	TotI	720	720	720	720	720	3600
	T <sub>min</sub> [°C]	1	3,5	7	4,8	2,5	
	T <sub>max</sub> [°C]	23,3	30,7	25,3	26,5	26,7	
	<b>T<sub>avr</sub>= en °C</b>	<b>12,12</b>	<b>15,4</b>	<b>14,58</b>	<b>13,45</b>	<b>13,9</b>	
<b>Period 2</b> [16/05_14/06]	T<18°C	12	45	18	16	0	91
	T>18°C	707	673	702	701	720	3503
	T>27°C	524	333	358	380	533	2128
	<b>18°C &lt; T &lt; 27°C</b>	<b>184</b>	<b>340</b>	<b>344</b>	<b>321</b>	<b>187</b>	<b>1376</b>
T <sub>qvr</sub> RETS=27,25	T=18°C	1	2	0	3	0	6
	T=27°C	4	3	5	8	4	24
T <sub>avr</sub> S, A=29,68	TotI	720	720	720	720	720	3600
	T <sub>min</sub> [°C]	15,9	13,5	15,9	15,6	18,6	



Number of hours		2012	2013	2014	2015	2016	Totals
	T <sub>max</sub> [ °C]	41,9	39,9	38,3	40,1	44,8	
	T <sub>avr</sub> [ °C]	<b>30,49</b>	<b>26,53</b>	<b>27,1</b>	<b>27,47</b>	<b>30,986</b>	
<b>Period 3</b> <b>[16/08_14/09]</b>	T<18°C	0	0	0	0	0	0
	T>18°C	720	720	720	720	720	3600
	T>27°C	556	549	689	575	655	3024
	<b>18°C&lt;T&lt;27°C</b>	<b>164</b>	<b>171</b>	<b>31</b>	<b>145</b>	<b>65</b>	<b>576</b>
	T=18°C	0	0	0	0	0	0
	T=27°C	5	4	4	1	5	19
T <sub>avr</sub> RETS=30,25	Totl	720	720	720	720	720	3600
T <sub>avr</sub> S, A=29,305	T <sub>min</sub> [ °C]	19,3	19,5	24,5	18,2	22	
	T <sub>max</sub> [ °C]	44,2	41,5	43,3	43	41,5	
	T <sub>avr</sub> [ °C]	<b>31,07</b>	<b>30,85</b>	<b>34,18</b>	<b>31,17</b>	<b>32,846</b>	
<b>Period 4</b> <b>[16/11_15/12]</b>	T<18°C	624	664	529	626	605	3048
	T>18°C	94	55	182	92	109	532
	T>27°C	0	0	4	0	0	4
	<b>18°C&lt;T&lt;27°C</b>	<b>94</b>	<b>55</b>	<b>178</b>	<b>92</b>	<b>109</b>	<b>528</b>
	T=18°C	2	1	9	2	6	20
	T=27°C	0	0	2	0	0	2
T <sub>avr</sub> RETS=13,5	Totl	720	720	720	720	720	3600
T <sub>avr</sub> S, A=12,56	T <sub>min</sub> [ °C]	3,6	3,7	5,1	6	7,6	
	T <sub>max</sub> [ °C]	23,2	24,6	27,9	23,2	24	
	T <sub>moy</sub> [ °C]	<b>12,79</b>	<b>11,81</b>	<b>15,19</b>	<b>13,21</b>	<b>14,3</b>	

**Table 6.** Evolution of the real humidity of the seasons' limit intervals; of Ghardaïa site, during the last five years from (2012 to 2016), and compared with those of the German Precision Station of (10 minutes) and also with the RET Screen data of (1980-2006)

Number of ours		2012	2013	2014	2015	2016	Totals
<b>Period.1</b> <b>[14/02_15/03]</b>	H<25	89	121	69	85	113	477
	H>=76	8	4	16	47	0	75
	<b>25&lt;=H&lt;=75</b>	<b>623</b>	<b>595</b>	<b>635</b>	<b>588</b>	<b>607</b>	<b>3048</b>
H <sub>avr</sub> RETS=44.4 %	Totals.1	720	720	720	720	720	3600
H <sub>avr</sub> S, A= 42,07 %	H-max %	80,5	80,5	90	97,5	69,15	
	H-min %	17,5	14,5	10,5	13	15	
	<b>H-moy %</b>	<b>40,24</b>	<b>35,72</b>	<b>44,52</b>	<b>44,52</b>	<b>37,89</b>	
<b>Period.2</b> <b>[16/05_14/06]</b>	H<25 %	470	412	303	312	481	1978
	H>=76 %	0	0	5	0	0	5
	<b>25&lt;=H&lt;=75 %</b>	<b>250</b>	<b>308</b>	<b>412</b>	<b>408</b>	<b>239</b>	<b>1617</b>
H <sub>moy</sub> RETS=29.1 %	Totals.2	720	720	720	720	720	3600
H <sub>avr</sub> S, A=27,12 %	H-max %	43,5	56	79,5	56	60,5	
	H-min %	7,5	6	9	7	7,5	
	<b>H-avr %</b>	<b>21,76</b>	<b>26,65</b>	<b>30,58</b>	<b>26,94</b>	<b>22,74</b>	
<b>Period.3</b> <b>[16/08_14/09]</b>	H<25 %	320	301	471	148	326	1566
	H>=76 %	0	11	0	11	0	22
	<b>25&lt;=H&lt;=75 %</b>	<b>400</b>	<b>408</b>	<b>249</b>	<b>561</b>	<b>394</b>	<b>2012</b>
H <sub>avr</sub> RETS=30,45 %	Totals.3	720	720	720	720	720	3600
H <sub>avr</sub> S, A=26,34 %	H-max %	68,5	90	50,5	89	75,5	
	H-min %	9	11,5	10	13	14	
	<b>H-avr %</b>	<b>27,69</b>	<b>31,69</b>	<b>22,8</b>	<b>35,78</b>	<b>26,84</b>	
<b>Period.4</b> <b>[16/11_15/12]</b>	H<25	0	16	22	9	4	51
	H>=76	26	120	43	58	121	368
	<b>25&lt;=H&lt;=75</b>	<b>694</b>	<b>584</b>	<b>655</b>	<b>653</b>	<b>595</b>	<b>3181</b>
H <sub>avr</sub> RETS=56.55%	Totals.4	720	720	720	720	720	3600
H <sub>avr</sub> S, A=54.68%	H-max %	87,5	95	86,5	95	95	
	H-min %	30,5	21	20,5	20,5	24	
	<b>H-avr %</b>	<b>53,3</b>	<b>56,56</b>	<b>49,79</b>	<b>55,85</b>	<b>58,18</b>	

## 9. CALCULATION OF THE AVERAGE REAL THERMAL LENGTH OF EACH SEASON

In Table 7, we see that the average length of spring and autumn are shorter in comparison with summer and winter, represent respectively; 54 days, 52 days, 135 days and 124 days, during the five years study. In the two previous Tables 8

and 9, we note that the full south orientation is better compared to the studied East-South orientation 35° (real state of housing), because the duration of sunshine of hot periods of the latter and more significant than the first (due south). Therefore, there is more consumption linked to air conditioning (same comments for Figures 30, 31, 32 and 33).

**Table 7.** Average length of each Ghardaïa season [2012-2016]

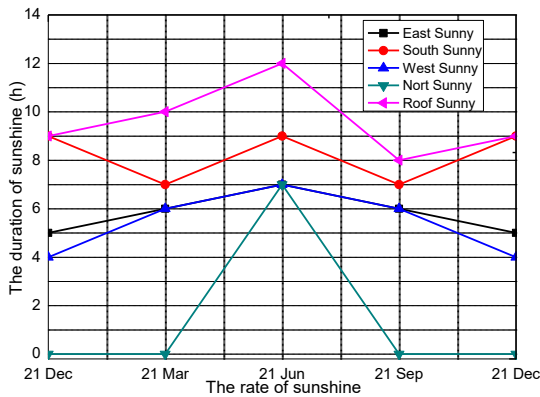
	Heating diagram	Air conditioning diagram	DJC, DJF (Weather)	Average
Winter	135	127	110	<b>124</b>
Springer	51	54	58	<b>54</b>
Summer	138	141	126	<b>135</b>
Autumn	41	43	71	<b>52</b>
Totals	365	365	365	<b>365</b>

**Table 8.** Sunrise and sunset at the start of each season; duration of sunshine of each face and the sunshine rate for each face in Ghardaïa, for a clear sky facing south

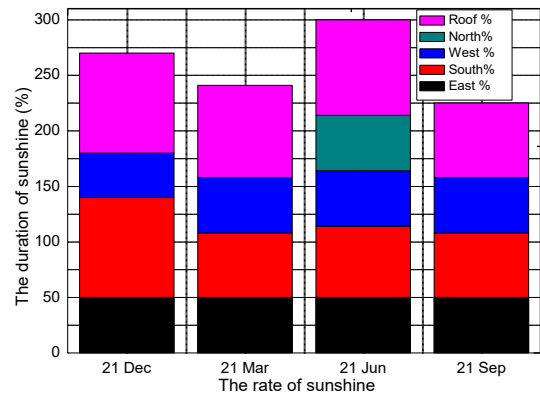
	Sunrise	Sunset	Day length	Duration of sunshine due south orientation									
				E	%	S	%	O	%	N	%	T	%
<b>21 D</b>	07 <sup>h</sup> 43'	17 <sup>h</sup> 44'	10 <sup>h</sup> 01'	05 <sup>h</sup>	<b>50</b>	09 <sup>h</sup>	<b>90</b>	04 <sup>h</sup>	<b>40</b>	00 <sup>h</sup>	<b>00</b>	09 <sup>h</sup>	<b>90</b>
<b>21 M</b>	06 <sup>h</sup> 47'	18 <sup>h</sup> 57'	12 <sup>h</sup> 10'	06 <sup>h</sup>	<b>50</b>	07 <sup>h</sup>	<b>58</b>	06 <sup>h</sup>	<b>50</b>	00 <sup>h</sup>	<b>00</b>	10 <sup>h</sup>	<b>83</b>
<b>21 J</b>	05 <sup>h</sup> 39'	19 <sup>h</sup> 55'	14 <sup>h</sup> 16'	07 <sup>h</sup>	<b>50</b>	09 <sup>h</sup>	<b>64</b>	07 <sup>h</sup>	<b>50</b>	07 <sup>h</sup>	<b>50</b>	12 <sup>h</sup>	<b>86</b>
<b>21 S</b>	06 <sup>h</sup> 32'	18 <sup>h</sup> 42'	12 <sup>h</sup> 10'	06 <sup>h</sup>	<b>50</b>	07 <sup>h</sup>	<b>58</b>	06 <sup>h</sup>	<b>50</b>	00 <sup>h</sup>	<b>00</b>	08 <sup>h</sup>	<b>67</b>

**Table 9.** Sunrise and sunset at the start of each season; duration of sunshine of each facade as well as the rate of sunshine for each facade in Ghardaïa, for a clear sky east\_south orientation with 35 ° [the case study (accommodation location)]

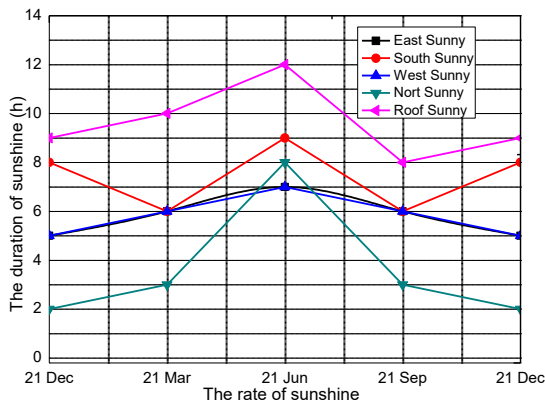
	Sunrise	Sunset	Day length	Duration of sunshine orientation East_South of 35° (real situation)									
				E	%	S	%	O	%	N	%	T	%
<b>21 D</b>	07 <sup>h</sup> 43'	17 <sup>h</sup> 44'	10 <sup>h</sup> 01'	05 <sup>h</sup>	<b>50</b>	08 <sup>h</sup>	<b>80</b>	05 <sup>h</sup>	<b>50</b>	02 <sup>h</sup>	<b>20</b>	09 <sup>h</sup>	<b>90</b>
<b>21 M</b>	06 <sup>h</sup> 47'	18 <sup>h</sup> 57'	12 <sup>h</sup> 10'	06 <sup>h</sup>	<b>50</b>	06 <sup>h</sup>	<b>50</b>	06 <sup>h</sup>	<b>50</b>	03 <sup>h</sup>	<b>25</b>	10 <sup>h</sup>	<b>83</b>
<b>21 J</b>	05 <sup>h</sup> 39'	19 <sup>h</sup> 55'	14 <sup>h</sup> 16'	07 <sup>h</sup>	<b>50</b>	09 <sup>h</sup>	<b>64</b>	07 <sup>h</sup>	<b>50</b>	08 <sup>h</sup>	<b>57</b>	12 <sup>h</sup>	<b>86</b>
<b>21 S</b>	06 <sup>h</sup> 32'	18 <sup>h</sup> 42'	12 <sup>h</sup> 10'	06 <sup>h</sup>	<b>50</b>	06 <sup>h</sup>	<b>50</b>	06 <sup>h</sup>	<b>50</b>	03 <sup>h</sup>	<b>25</b>	08 <sup>h</sup>	<b>67</b>



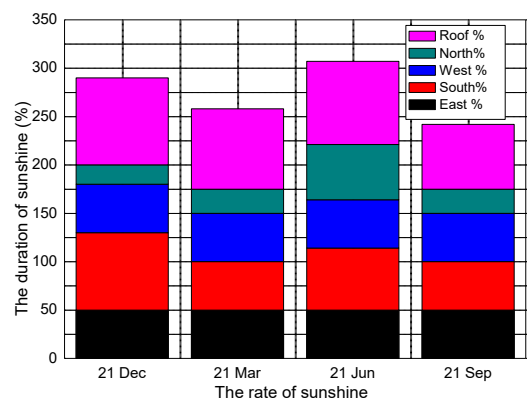
**Figure 30.** The duration of the sunshine on the surface of each facade during the year (hour) of Full south orientation in Ghardaïa



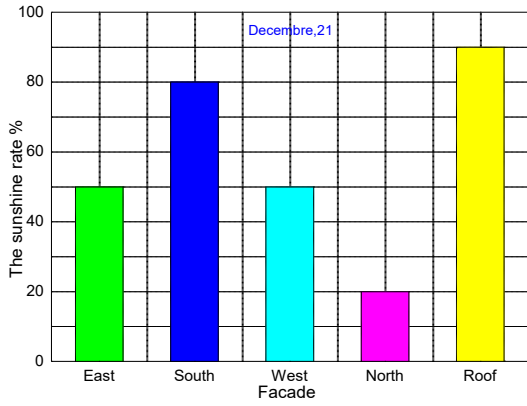
**Figure 32.** The duration of the sunshine on the surface of each facade during the year (%) of Full south orientation in Ghardaïa



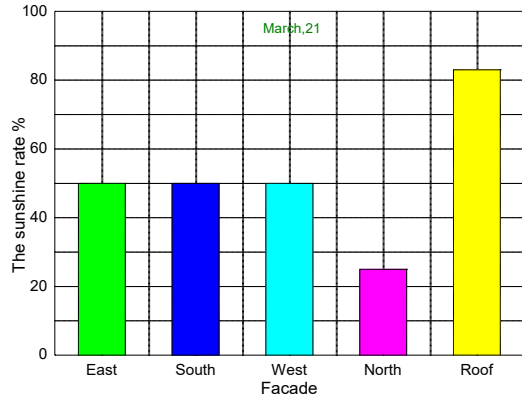
**Figure 31.** The duration of the sunshine on the surface of each facade during the year (hour) of East-South Orientation with 35 ° in Ghardaïa [The study case]



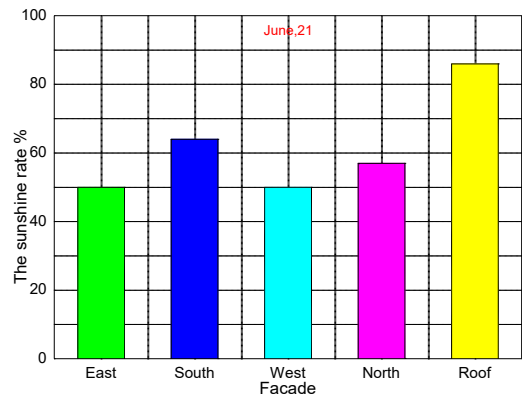
**Figure 33.** The duration of the sunshine on the surface of each facade during the year (%) of East\_South Orientation with 35 ° in Ghardaïa [The study case]



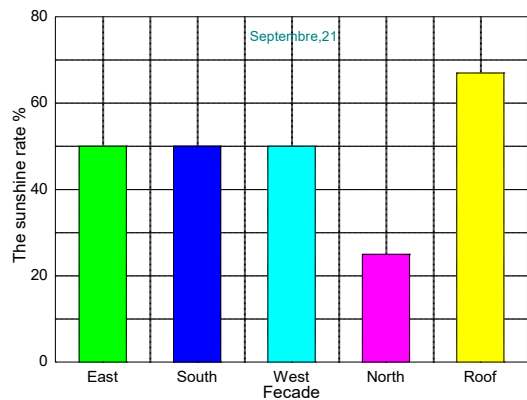
**Figure 34.** The sunshine rate of each façade on December 21



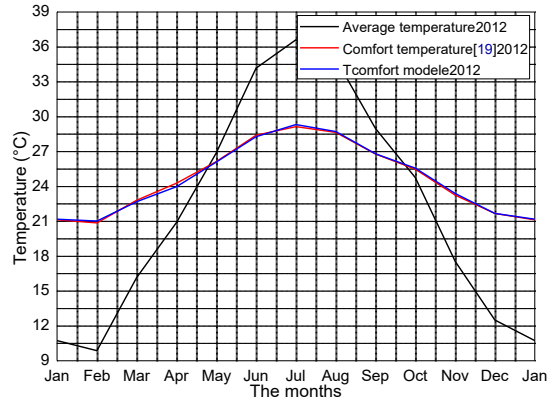
**Figure 35.** The rate of sunshine of each Facade on March 21



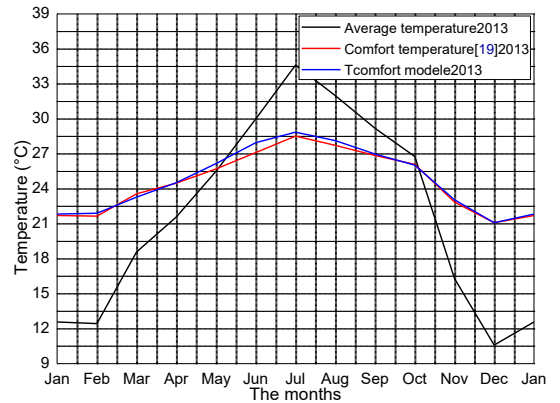
**Figure 36.** The rate of sunshine of each Facade on June 21



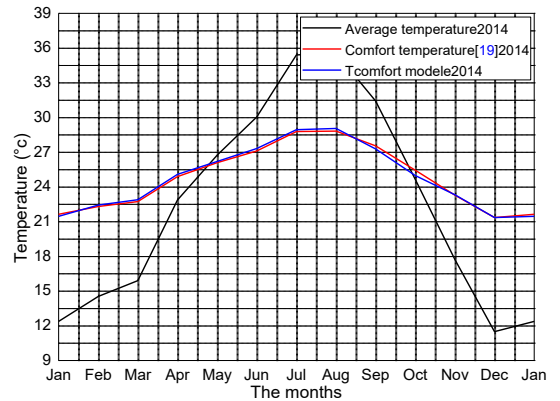
**Figure 37.** The rate of sunshine of each Facade on September 21



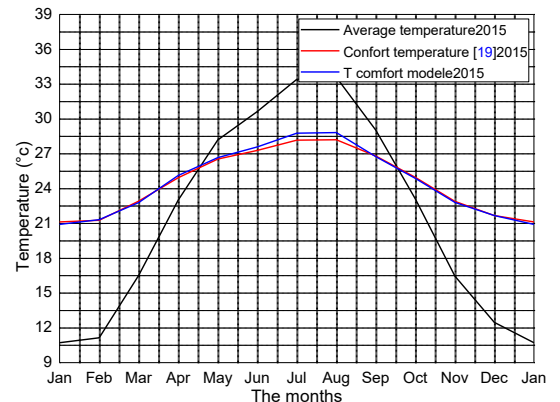
**Figure 38.** Comfort temperatures as a function of average monthly temperatures 2012, compared with stool [19]



**Figure 39.** Comfort temperatures as a function of average monthly temperatures for 2013, compared with stool [19]



**Figure 40.** Comfort temperatures as a function of average monthly temperatures for 2014, compared with stool [19]



**Figure 41.** Comfort temperatures as a function of average monthly temperatures for 2015, compared with stool [19]

**Table 10.** The days of average energy expenditure in all seasons for the five selected years [2012-2016]

Period of the Selected five-year seasons [2012_2016]	Number of day in the selected season	Number of ours of season	Number of hours of natural comfort without heating and without air conditioning	Number of days expenses [heating - air conditioning]
P1[01/12_28/02]	90	2160	215h $\approx$ 9 Day	<b>81</b>
P2[01/03_31/05]	92	2208	1165h $\approx$ 49 Day	<b>43</b>
P3[01/06_31/08]	92	2208	360h $\approx$ 15 Day	<b>77</b>
P4[01/09_30/11]	91	2184	927h $\approx$ 39 Day	<b>52</b>
<b>Totals</b>	<b>365</b>	<b>8760</b>	<b>112</b>	<b>253</b>

**Table 11.** Comfort real temperature in the Ghardaïa region

	2012		2013		2014		2015		2016	
	Tavr	Tconf	Tavr	Tconf	Tavr	Tconf	Tavr	Tconf	Tavr	Tconf
<b>January</b>	10.73	21.18	12.57	21.83	12.38	21.46	10.72	20.92	13.9323	22.11
<b>February</b>	09.87	21.02	12.43	21.91	14.54	22.43	11.15	21.31	14.7552	22.50
<b>March</b>	16.15	22.68	18.57	23.29	15.90	22.89	16.50	22.78	17.1516	23.08
<b>April</b>	20.90	23.98	21.58	24.52	22.87	25.09	23.00	25.13	22.7367	24.98
<b>May</b>	26.89	26.09	25.52	26.17	26.75	26.21	28.19	26.67	27.2742	26.34
<b>June</b>	34.16	28.27	30.00	27.95	30.04	27.32	30.62	27.59	31.8233	27.76
<b>July</b>	36.61	29.31	34.61	28.86	35.40	28.94	33.41	28.77	34.3759	28.78
<b>August</b>	34.96	28.72	32.00	28.13	35.57	29.05	33.59	28.82	32.9968	28.26
<b>September</b>	28.98	26.81	29.20	26.98	31.43	27.29	29.04	26.75	29.4333	27.03
<b>October</b>	24.75	25.57	26.77	26.02	24.64	24.98	23.11	24.88	24.9839	25.12
<b>November</b>	17.55	23.39	16.30	23.05	17.71	23.31	16.45	22.81	16.5433	23.21
<b>December</b>	12.50	21.68	10.59	21.08	11.49	21.36	12.47	21.67	12.3000	21.52

Figures 34, 35, 36 and 37 show the rate of sunshine of each Facade on March 21st, June 21st, September 21st and December 21st, however the Comfort temperatures as a function of average monthly temperatures 2012, 2013, 2014 and 2015 compared with stool [19] are presented in the Figures 38, 39, 40 and 41. The days of average energy expenditure in all seasons for the five selected years [2012-2016] are mentioned in the Table 10, where the recapitulation Table 11 presents the comfort real temperature in the Ghardaïa region. All the last figures and tables are presented to enrich and detail the previous explanations.

## 10. CONCLUSION

In this study I determined exactly the real hygrothermal parameters of the Ghardaïa region of each season as well as the daily lengths of; (summer period with 135 days, winter period 124 days, spring 54 days and autumn 52 days) by a new easy graphical method will allow to determine the beginning and the end of each season (an integral method). In this study, we also determine the comfort temperatures of each ego in this region (Ghardaïa). The real determination of the seasons and parameters of the Ghardaïa region give a real solid scientific platform, to decision makers and investors for the development of this region as well as regions of the same climate (Sahara), more than that opened a window on the integration of renewable energies and especially in the thermal field (heating, air conditioning, domestic hot water, etc.). According to this technique, We have proved that the summer period is predominant on the thermal side in our region, follow it by the winter period; This means a mad consumption of the country's energy capacities, which affects not only our economic balance, but also our environment and our living environment. Therefore, the authorities must consider these conditions in the future in their development policies for these regions. The latter made from the integration

of new socioeconomic, thermal, ecological and environmental solutions; such as green dams, water dams, nanomaterial, intelligent materials, new bioclimatic cities with low energy consumption, etc. The results clearly showed the moderate spring and fall seasons, which were few in this region. To also combat and remedy high-energy consumption and reduce heat waves; solutions must be found to increase the interval between these seasons (spring and autumn). This new integral method, reliable, modern and profitable, allows determining exactly the heating periods and cooling periods of any zone, region and country.

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