



An analytical study for the impact of climate change on the occurrence of earthquakes since 2005 until 2021 In Sulaymaniyah / Iraq

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Abstract

Based on a study for 16 years of earthquake data in Sulaymaniyah city from 2005 to 2021 almost 11000 earthquakes were recorded, the degree intensity (4.4 Richter) was chosen to be the critical degree for the earthquake and for humans to feel it, After 2005 there was an increase in the number of earthquakes until 2012, in 2013 it was the peak witch reached 238 hitting, in 2014 there was a significant decreasing and kept down, climate change data focused on months of August, October, November and December, changes that occurred in number of sunny hours were studied there was a significant change in 2005 with value (15.5 hours) which gradually decreased to (10.4 hours), there wasn't a clear evidence linked sunny hours to occurrence of earthquakes, Rainfall tends to increase relatively in some years in December as well as (2007, 2009, 2012, 2013, 2016 and 2018) that were consecutive (67, 118, 98.3, 103.6, 185.8 and 315.1 mm) but no evidence connect rainfalls to earthquake occurrence, Temperatures in the months of the study were relatively similar in terms of rise and fall, but the month of December differed slightly in the years 2012 to 2017.No changes noted in October and November in atmospheric pressure values but in December there was a relative increase in most years of study, evaporation rates in December after 2016 there was a relative increase in evaporation rates.

Key words: Earthquakes, Earthquakes and climate change, Rainfall, temperature, wind

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Introduction

If temperatures continue to rise, they will have an impact on both our human society and the natural environment in the form of droughts, sea level rise, and floods. However, it now appears that global warming can also have an impact on another extremely rare class of events known as earthquakes [1].

As a result, the earthquake disaster has a significant impact on the long-term economic growth of the local area. Although the indirect economic damage caused by the earthquake has widely been acknowledged, quantitative quantification is still a challenging topic [2].

On a worldwide scale tectonic earthquakes produce movement between several large plates formed of the earth's crust or rock layer (about 15 in total) The material in the earth's mantle moves as a result of the heat produced at the earth's core which in turn drives that heat, A sudden slide that releases a massive amount of energy is what causes the earthquake the point where earthquakes begin and break the plates underground is known as focus and above the focus on the surface of the earth is called the epicenter, [3], During plate movement one plate gets submerged into the molten magma and another plate is moved across the top of it This plate rises up due to the heat of molten magma the plates keep on moving until they get stuck against each other Most earthquakes take place on the boundaries of the plates where one plate is forced further into the earth crust while another plate is move [4].

[5] Reported that significant increases in air temperature in the distant part may have been related to changes that occurred in geological activity. It remains a matter of speculation to point out that the climate change expected to occur in the coming decades could lead to similar geological changes. But scientists say there is enough evidence to take such a risk seriously. Some experts have already linked current levels of global warming to rockslides and landslides in mountainous areas, it was noted that there is no evidence confirming that current levels of global warming affect events such as the earthquake that struck China last week, killing hundreds of people, and the

volcanic eruption in Iceland that paralyzed air traffic throughout Europe [6].

Studies conducted in Germany indicate that the Earth's crust can sometimes be close to collapse, so that slight changes in surface pressure as a result of heavy rain can cause earthquakes. Tropical storms, snowfall, and changes in tides were linked to changes in seismic activity [7].

Studies in the field of building theoretical models and projecting current trends into the future indicate an increased risk for a wide range of geological phenomena and landforms in a warming world, while observations indicate that an increase in average Earth temperatures may provoke a dangerous response. Of the Earth's crust and the upper layer beneath it. also called on the United Nations Intergovernmental Climate Committee to deal more frankly and openly with assessing the effects resulting from climate change through the influence of human activities and their resulting consequences [8].

Materials and Methods

This study concentrated on the months of august, October, November and December [9], because through follow-up noticed that these months earthquakes of medium or more magnitude occurred and to find a link between climate elements changing and the occurrence of local earthquakes.

Iraq generally consists of two structural units the Continental platform and regional concavity these two units are divided into regions and belts the Continental platform it is divided into stable and unstable the stable covers the western and south western part of Iraq it is characterized by the low thickness of the sedimentary cover and folds since Iraq located in general and the city of Sulaymaniyah in particular in Arabian plate and located next to two micro plate (Persian plat and Anatolian plate)[10]. The city of Sulaymaniyah can be considered relatively unstable in terms of seismic activity due to its direct contact with the Persian plat border [11].

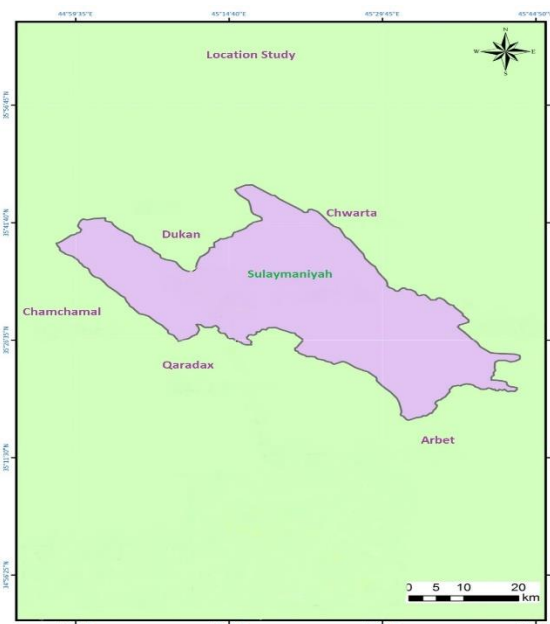
This work includes Sulaymaniyah 16 year's averages of temperature, rainfall, winds speed sunshine, atmospheric pressure, evaporation and earthquake data starting from 2005 to 2021 the annual of these dates provided by Sulaymaniyah Directorate of Meteorology and Seismology, the research adopts the following methodologies a regional study selecting the study region and information collection for the purpose of this research, collection all available information regarding earthquakes that occurred over the past years from 2005 to 2021 in terms of strength and number of occurrences then Gathering information about the amounts of rain falling in the Sulaymaniyah especially the months in which it rains heavily and trying to find a relationship between them and the incidence of earthquakes in the region, Documenting the extreme high and low temperatures and summarizing them in excel sheets and comparing them with other available information on the amounts of rain, The research region was in the province of Sulaymaniyah (fig. 1) including the city of Sulaymaniyah in Iraq's northeast, It is distinguished by the overall appearance of its surface. It is hilly, with valleys and tiny plains surrounding it. The city is situated between longitude ($35^{\circ}.49'.00''$ N) and latitude ($45^{\circ}.25'.00''$ E) on the western slopes of the Azmar Mountains. From north to south, the city is bordered by many mountain ranges. Sulaymaniyah offers 3.5 percent on sloping land. The city's northernmost point is 885 meters. The northern end is 800 meters above sea level, while the southern end is 800 meters above sea level.

Results and discussion

Earthquake in Sulaymaniyah

from 2005 until 2021 around 11,000-time earthquake hits this city but the strongest

earthquake recorded by the Meteorology Department was in the year 2017 which hit Sulaymaniyah city (Darbandikhan) town known as Halabja earthquake with a magnitude of (7.3Richter).



Figurer 1, location study

The city's climate may be classified as temperate or (the Mediterranean climate of the mountain) based on climate classifications conducted by researchers and professionals in this field, and its most important climatic features are:

- The average yearly temperature is (18.74°C).
- In terms of wind, the prevalent winds are as seen in the city's wind rose (Northeast and usually very fast).
- Rain, primarily in the winter and spring, with little rain in the summer. In 2018, greater yearly rain was recorded (1273.8mm).

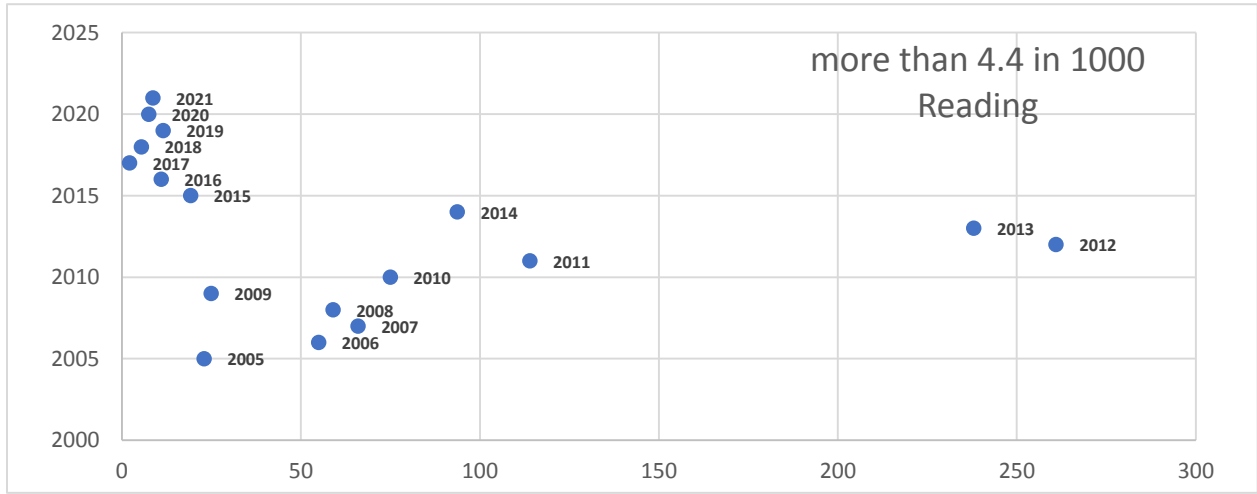


Fig. 2. Data numbers for earthquakes that higher than 4.4 Richter per year. ,Source: Directorate of Meteorology and Seismology in Sulaymaniyah, Iraq.

Figure 2 is based on the percentage of earthquakes whose magnitude exceeded 4.4 Richter out of every thousand earthquakes that hit the province during the years of the study, this degree (4.4 Richter) was adopted because humans feel it and hear the sound of the earthquake in addition to the movement of

some things and materials [12], It is noted that there was a significant increase in the number of earthquakes that hit the city until year 2012 when it reached 261 earthquakes but from 2013 the number of earthquakes began to decrease significantly until it reached 8.7 hit in thousand earthquakes in the year 2021. [13].

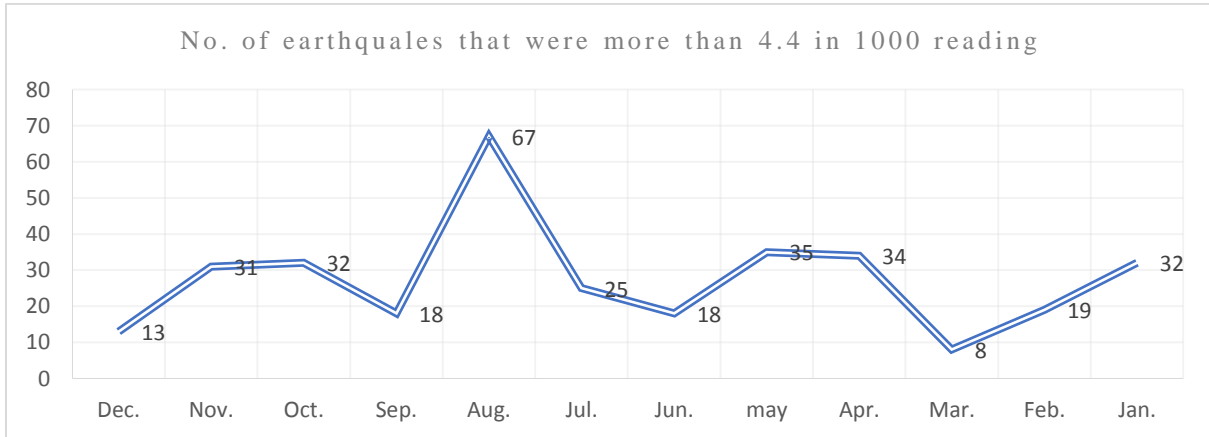


Fig. 3. Monthly average of the numbers earthquakes Shaking magnitude that struck Sulaymaniyah during study years, Source: Directorate of Meteorology and Seismology in Sulaymaniyah, Iraq ;

From (fig. 3) When making a comparison between the months of the study years in terms of the number of times earthquakes higher than 4.4 Richter occurred find that the month of August had more earthquakes than the rest of

the month with a significant increase with the number reaching (67 hit) and after that the month of May with the number of earthquakes reaching (35hit) [14].

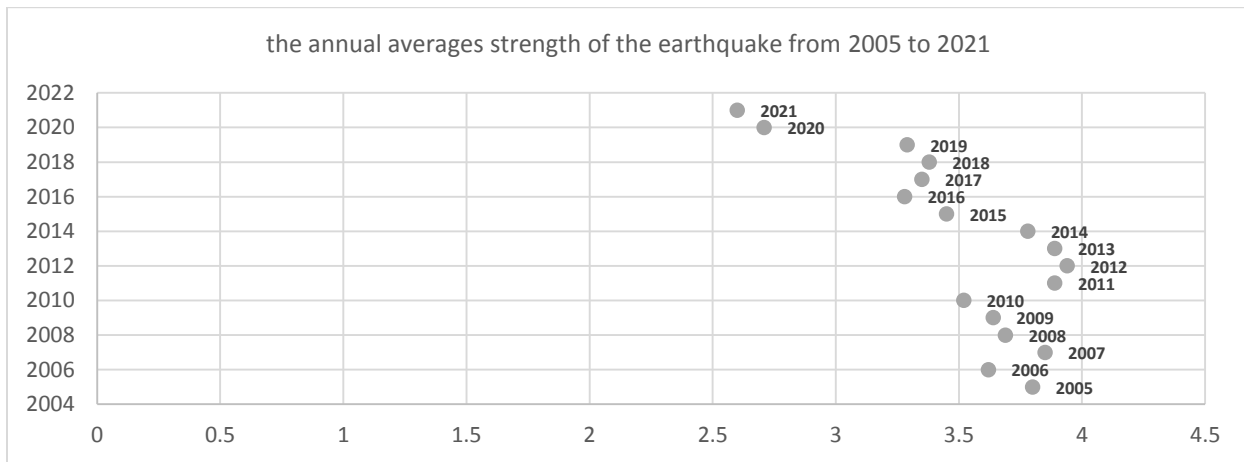


Fig. 4. degree Annual averages of the Shaking intensity earthquakes, Source: Directorate of Meteorology and Seismology in Sulaymaniyah, Iraq

Figure No. 4 shows the average annual earthquake strength during the years of the study. It is noted that the shaking strength in the years 2012, 2013, and 2014 was (3.89, 3.94, and 3.89) respectively were is the highest value but its notes after season of 2018-2019 the earthquakes value have decreased the the lowest ever record, , year of 2011 which was called the year of earthquakes globally [15] the

annual average strength of earthquakes in 2011 was (3.89) which was the highest during the years of the study. From Figure 4, when running Trendline it is noted that there is a relative decrease in the rates of the strength of the tremors that struck the city especially in the recent years of 2020 and 2021 where they reached 2.72 and 2.6 respectively.

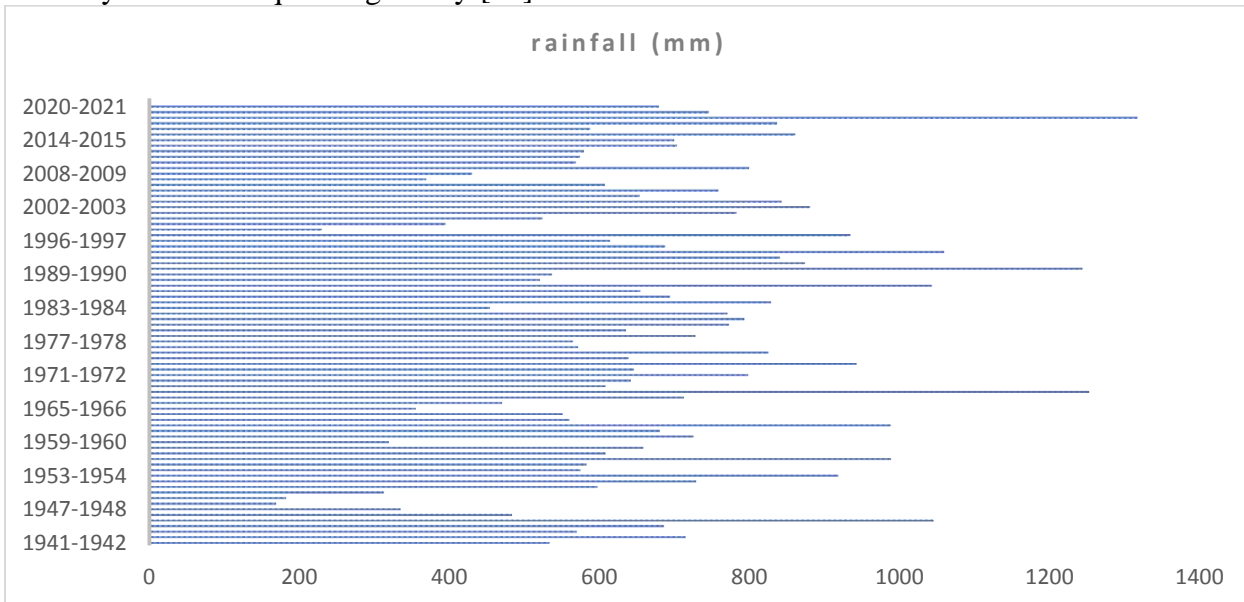


Fig. 5. Annual rainfall amounts in Sulaymaniyah for period 1941 until 2021, Source: Directorate of Meteorology and Seismology in Sulaymaniyah, Iraq

Figure (5) shows the seasons with the highest rainfall whose amounts exceeded 900 mm and were limited (1945-1946), (1953-1954), (1956-

1957), (1968-1969), (1973-1974), (1987-1988), (1991-1992), (1994-1995), (1997-1998) and the season (2018-2019), which had the highest

rainfall, amounting to 1317.8 mm. also 1968-1969 had a big of rainfall reached 1252.8mm. From the years of study, it was noted that this

city did not suffer from a scarcity of rain except in a few years. Rather, the amounts of rain in most years exceeded the danger of drought

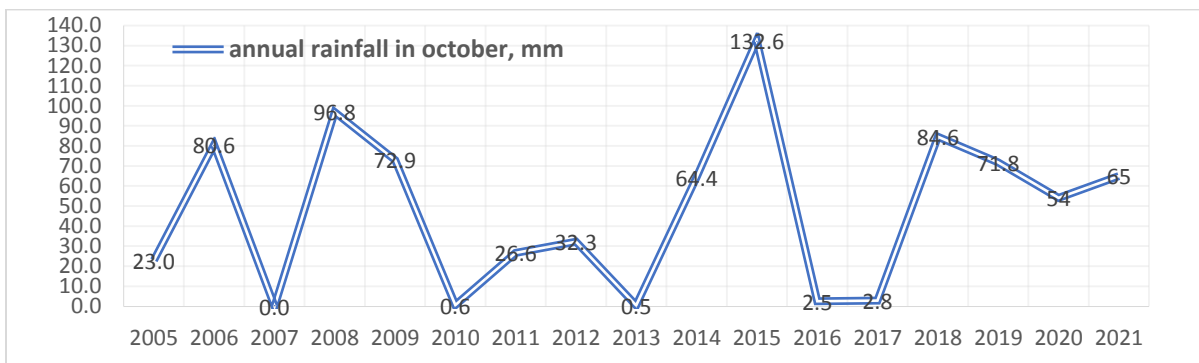


Fig. 6. Annual rainfall amounts in Sulaymaniyah for October throw the period 2005 until 2021, Source: Directorate of Meteorology and Seismology in Sulaymaniyah, Iraq

Rainfall rates averages in October for the study years 2005-2021 (fig. 6) were (45.5 mm) there were a significant decrease that occurred in the years (2007,2010, 2013, 2016 and 2017) which were (0.0, 0.6, 0.5, 2.5 and 2.8) mm) respectively, the amounts rain returned to their

normal levels after 2018. These changes were accompanied by changes in the magnitude of earthquakes in 2011 the magnitude of earthquakes increased to (3.89 Richter) and (3.94 Richter) in 2012 after it was (3.54 Richter) in 2010 [16].

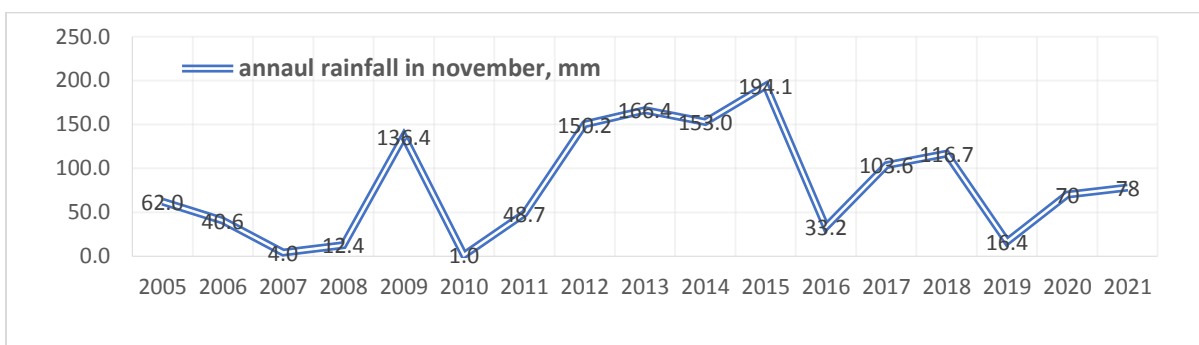


Fig. 7. Annual rainfall amounts in Sulaymaniyah for November through the period 2005 until 2021, Source: Directorate of Meteorology and Seismology in Sulaymaniyah, Iraq

Figure (7) show changes the amount of rainfall in November through the study years Rainfall amounts fluctuated between low and high in some years such as 2005, 2006, 2007 and others, the amounts of rain in this month

were at their lowest values in years (2007, 208, 2010, 2019) but in 2009, 2012, 2013, and others, the amounts of rain were good in this month, this month rainfall averages was 83.6mm. [17]

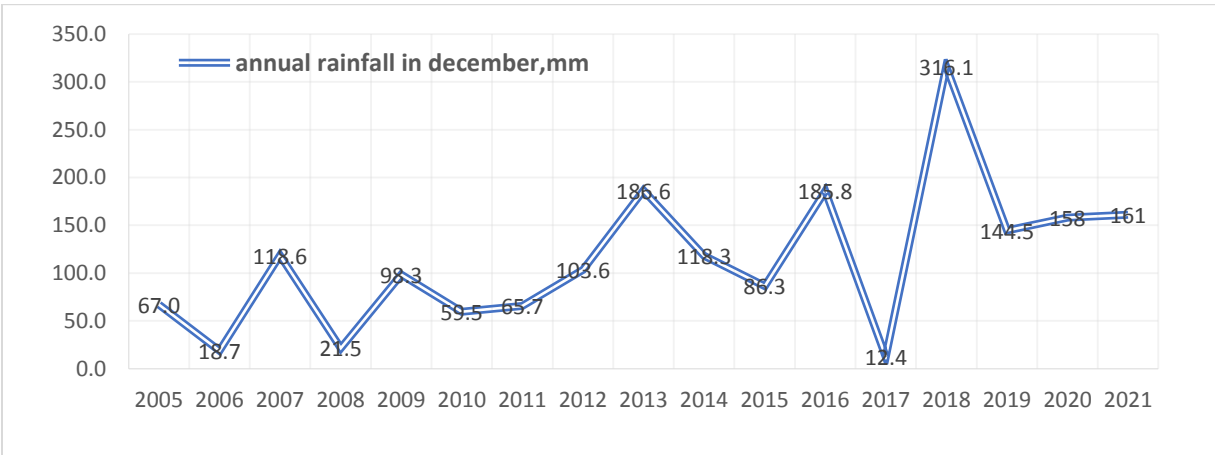


Fig. 8. Annual rainfall amounts in Sulaymaniyah for December through the period 2005 until 2021,Source: Directorate of Meteorology and Seismology in Sulaymaniyah, Iraq

The averages rainfall in December was 106.5 mm, there were relative increases in rainfall amounts this month as can be seen from the figure (fig. 8) these amounts decreased to the lowest levels reaching (18.7, 21.5, 12.4 mm) in the years (2006, 2008, 2017) respectively, From the available data there was no

precipitation in quantities that lead to plate displacement but in the 2018-2019 season the amounts of rain reached 1300 mm. the impact of climate change is manifested in the amount of surface water and the volume of groundwater recharge [18].

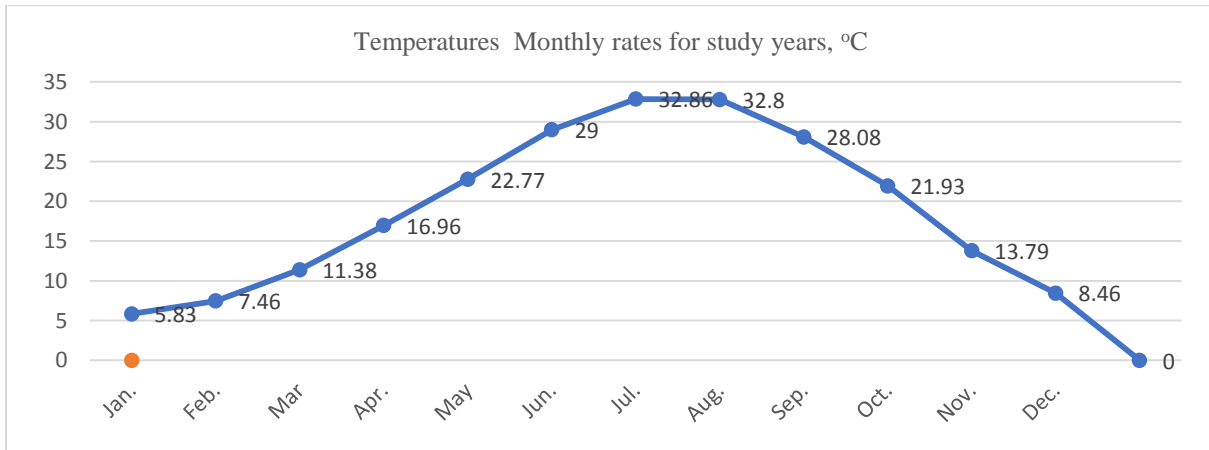


Fig. 9. Monthly Averages of Temperature in Sulaymaniyah through the period 2005 to 2021,Source: Directorate of Meteorology and Seismology in Sulaymaniyah, Iraq

From figure (9) July and August are the highest average temperatures for the years of study wasn't have any evidence linking the rise in temperatures and the heating of the earth and its interior with the occurrence of earthquakes

in our regions, especially since the Arabian plate on which Iraq is located is not active, but the aftershocks of earthquakes from Iran in particular are what affect our regions in particular [19].

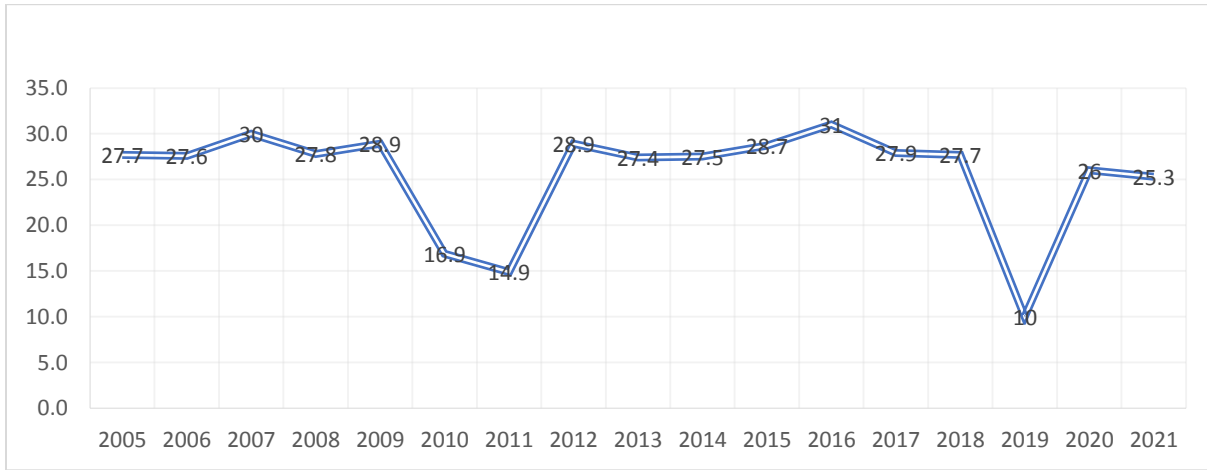


Fig. 10. Annual temperatures degree in Sulaymaniyah for October through the period 2005 until 2021, Source: Directorate of Meteorology and Seismology in Sulaymaniyah, Iraq

From figure (10) The temperatures in October have a significant decrease during the study period, in 2010 when it reached (16.9°C) and in 2011 which was (14.9 °C) and other drop was in 2019 when the temperature decreased to (10 °C) of the annual averages of the magnitude of

earthquakes after 2010 specifically in 2011 and 2012 the highest values were recorded (3.89 and 3.94 Richter) As for after 2019 there was a significant decrease in the magnitude of the earthquakes which reached 2.71Richter [20].

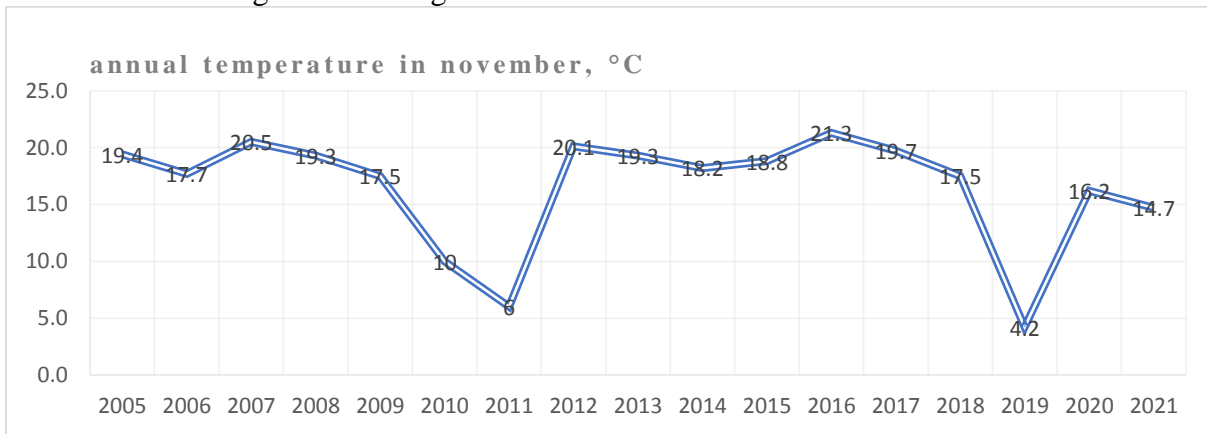


Fig. 11. Annual temperatures degree in Sulaymaniyah for November through the period 2005 until 2021. Source: Directorate of Meteorology and Seismology in Sulaymaniyah, Iraq

The average temperature in November (fig. 11) was (19.3°C) but it decreased during the same period in 2010 the temperatures degree reached (10°C) and in 2011 reached (6 °C) 2019 when the temperature decreased to (4.2 °C) of the annual averages of the magnitude of

earthquakes after 2010 specifically in 2011 and 2012 highest levels ever observed were found (3.89 and 3.94 Richter). After 2019 the magnitude of the earthquakes significantly decreased and reached 2.71 Richter [21].

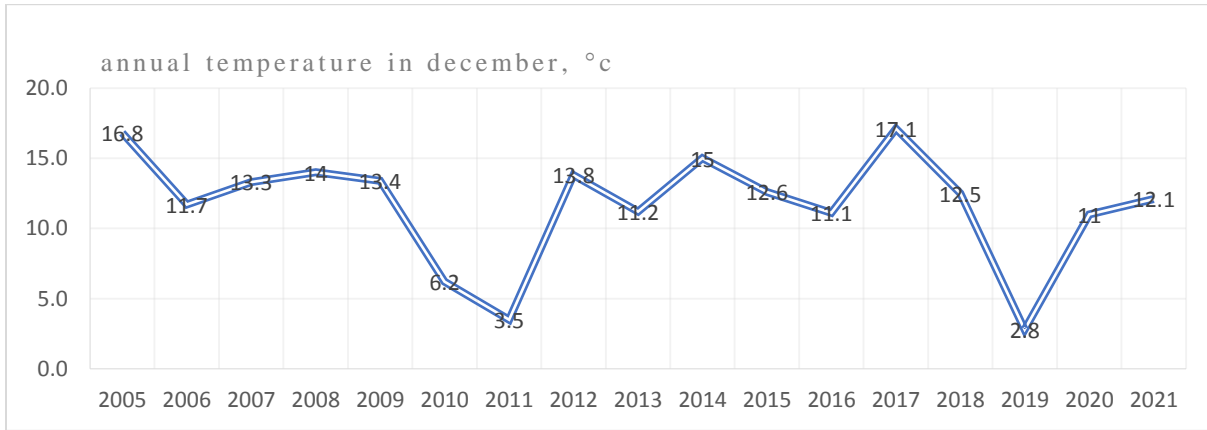


Fig. 12. Annual temperatures degree in Sulaymaniyah for December through the period 2005 until 2021. Source: Directorate of Meteorology and Seismology in Sulaymaniyah, Iraq

From figure (12) it's clear that the general average temperatures were not clearly changed except in two season (2011 and 2019) that decreased to the lowest degree in this month. In the years of study and in the three months except in two years and that was in the years 2012 and 2019. During these 15 years the maximum temperature increased by an average of (1.5 °C) This clear evidence of strong

changing climate in our region by increasing temperature in a way ecosystems have responded to these changes. Crop production suffers in our regions where changes in temperature will further stress the already limited productive because of the temperatures getting higher also grow seasons have become unstable that's leads to droughts condition which effect on the quality of yields [22].

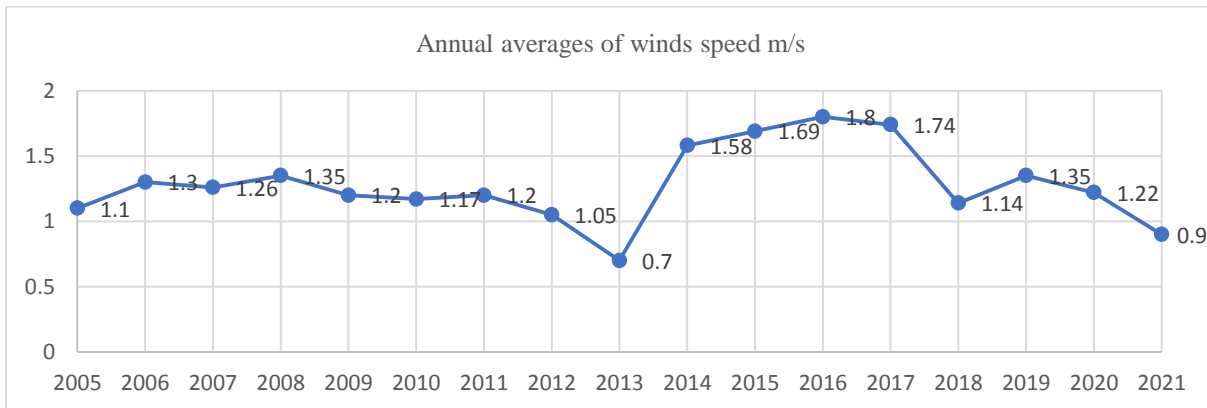


Fig. 13. The annual average wind speed in Sulaymaniyah through the period 2005 until 2021. Source: Directorate of Meteorology and Seismology in Sulaymaniyah, Iraq

From 2005 to 2011 average wind speeds were similar (almost 1.2m/s) like figure (13) shows but after that there was a slight decrease until 2013 (0.7m/s) and after that there was a significant increase in wind speeds until it reached its peak in 2017 (1.8m/s) and in 2018 (1.74m/s) then returned to their pre-2011 levels

[23]. The year 2017 also witnessed the highest values recorded for wind speeds it also recorded the highest earthquake that hit the city on 11/12/2017 specifically in the city of Darbandikhan which had magnitude of 7.3 on the Richter.[24].

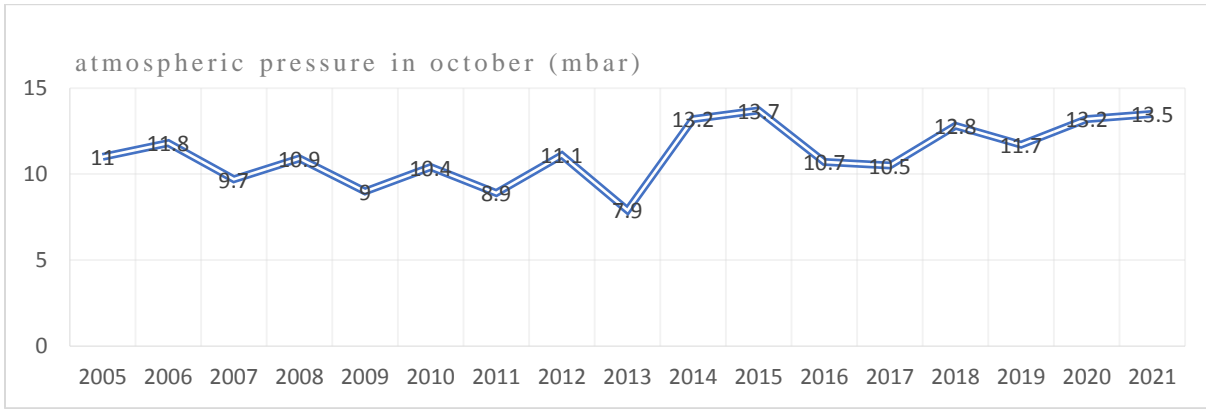


Fig. 14. atmospheric vapour pressure (mbar) degree in Sulaymaniyah for October through the period 2005 until 2021. Source: Directorate of Meteorology and Seismology in Sulaymaniyah, Iraq

Whereas, the years 2013 and 2014 had the highest number of earthquakes higher than (4.4 Richter) (261 and 238) respectively and the annual average of the magnitude were the highest (3.94 and 3.89 Richter) compared to the rest of the years and the importance of the pressure factor After the occurrence of

earthquakes three graphs were made for October, November and December separately, In October like (fig. 14) notice a significant change which is the highest since 2013 as the annual average of atmospheric pressure in the years 2014 and 2015 was the highest (13.2 and 13.7bar) [25].

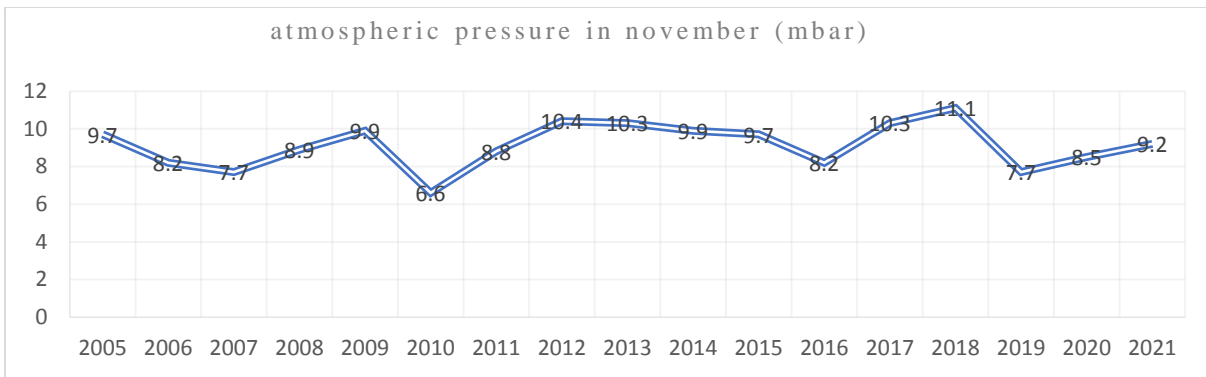


Fig. 15. Annual atmospheric pressure (mbar) degree in Sulaymaniyah Governorate for November through the period 2005 until 2021. Source: Directorate of Meteorology and Seismology in Sulaymaniyah, Iraq.

Figure (15) shows November month since there were no changes out of the ordinary or coincided with the recorded seismic values.

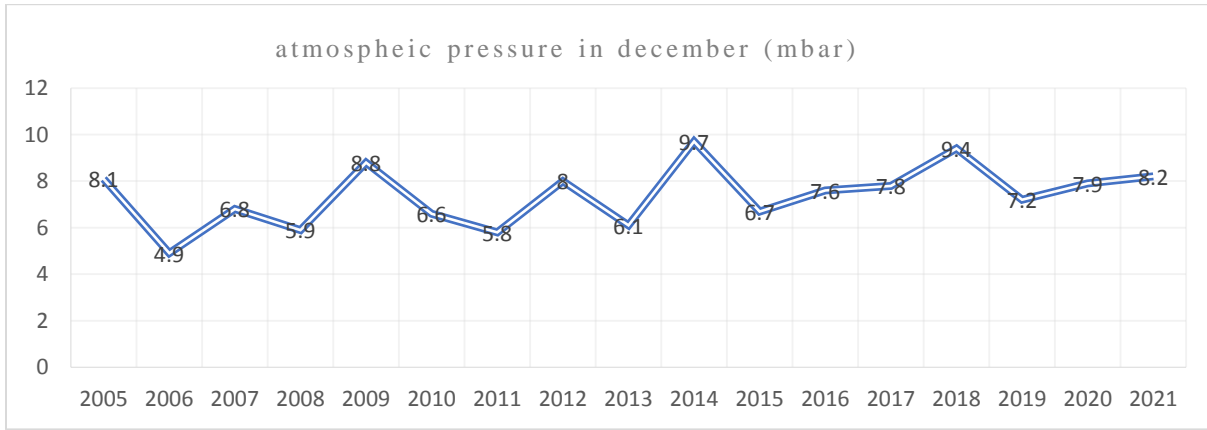


Fig. 16. atmospheric vapour pressure (mbar) degree in Sulaymaniyah Governorate for December through the period 2005 until 2021. Source: Directorate of Meteorology and Seismology in Sulaymaniyah, Iraq

In this month the highest reading of the average atmospheric pressure was recorded in the year 2014 which was at a rate of (9.7 bar) figure (16). In addition, the year 2014 was the second highest value of the annual average

earthquake magnitude recorded at a rate (3.89 Richter) Also the number of earthquakes higher than (4.4 Richter) was very high and reached 238 earthquakes [26].

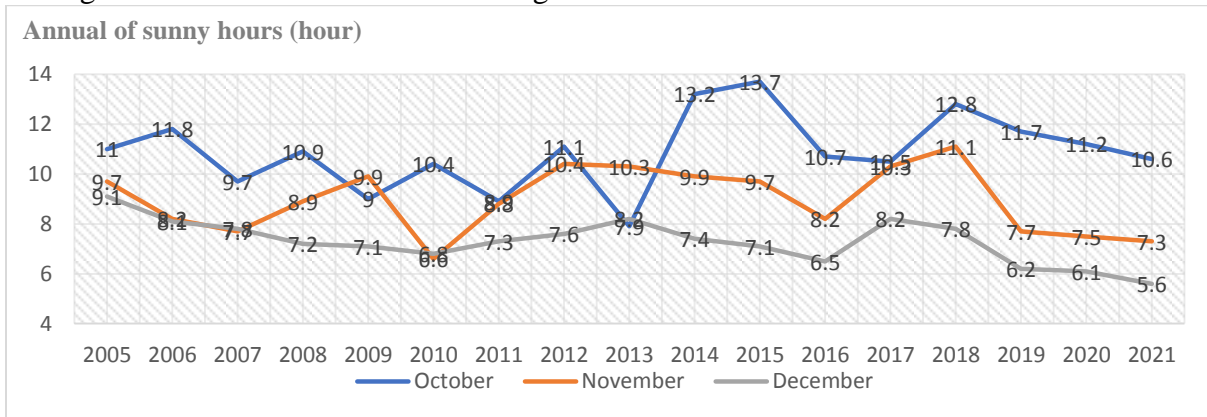


Fig. 17. annual average number of sunny hours in months of October, November and December. Source: Directorate of Meteorology and Seismology in Sulaymaniyah, Iraq

No sharp changes in the number of sunny hours were detected during the periods that witnessed the highest seismic tremors in the number of times, In figure (17) after the year 2013 which is the year numbers of earthquakes (higher than 4.4 on the Richter scale) was 261

which is the highest throughout the years of the study it is noted that there was a sharp increase in the number of sunny hours in October (13.7 hours) in the following year (2014) and the following year (2015) [27].

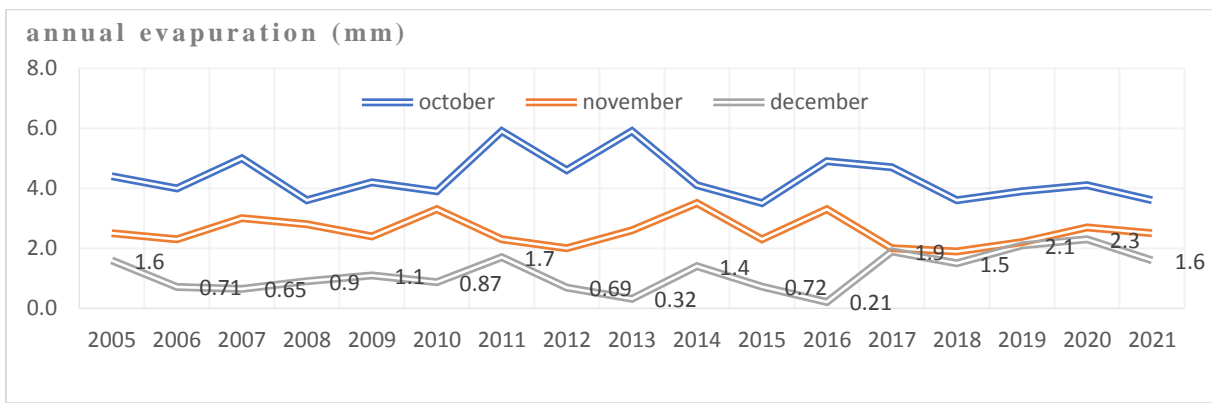


Fig. 18. The annual average Evaporation (mm) in the months of October, November and December.
Source: Directorate of Meteorology and Seismology in Sulaymaniyah, Iraq

The recorded annual evaporation rates show a difference in the rise and fall in their values (fig. 18). according to the temperatures in that year but there wasn't any relationship between them and the earthquakes of the earth [28].

Conclusion

In this modest study were not able to link any of the climate elements with the intensity of earthquakes locally Climate changes are actually occurring in most of its elements especially in temperatures which have actually risen by approximately one degree Celsius and the last time it rained in relatively large quantities was in the 2018-2019 season when the amount of rain reached 1317 mm. But these changes did not directly affect the Earth's interior or the movement of tectonic plates. Especially since our region is not seismically active, but the reality of this extremely important issue requires further studies.

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دراسة تحليلية عن تأثير التغيرات المناخية في حدوث الزلازل منذ سنة 2005 حتى 2021 في السليمانية / العراق

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 - تاريخ استلام البحث 2023/10/05 وتاريخ قبوله 2023/10/31.

الملخص

بناءً على دراسة لمدة 16 عاماً لبيانات الزلازل التي شهدتها مدينة السليمانية من عام 2005 إلى عام 2021، تم تسجيل ما يقرب من 11000 زلزال، وتم اختيار درجة الشدة (4.4 ريختر) لتكون الدرجة الحرجة للزلزال الذي يشعر به الإنسان بشكل مؤكد، وبعد عام 2005 هناك كانت زيادة في عدد الزلازل حتى عام 2012 وفي عام 2013 كانت الذروة حيث وصلت إلى 238 هزة، في عام 2014 كان هناك انخفاض كبير وظل منخفضاً إلى الآن، ركزت بيانات تغير عناصر المناخ على أشهر آب وتشرين الاول وتشرين الثاني بالإضافة إلى كانون الاول، والتغيرات التي حدثت في عدد الساعات المشمسة كانت واضحة في عام 2005 والتي كانت (15.5 ساعة) وانخفضت تدريجياً إلى (10.4 ساعة) ولم يكن هناك دليل واضح على ربط الساعات المشمسة بحدوث الزلازل، كميات هطول الأمطار مالت إلى الزيادة نسبياً في بعض السنوات ففي شهر كانون الاول كان (2007، 2009، 2012، 2013، 2016 و 2018) والتي كانت على التوالي (67، 118، 98.3، 103.6، 185.8 و 315.1 ملم) ولكن لا يوجد دليل يربط هطول الأمطار بحدوث الزلازل، درجات الحرارة في اشهر الدراسة كانت متشابهة التغير نسبياً من حيث الارتفاع و الانخفاض لكن شهر كانون الاول اختلفت قليلاً في السنوات 2012 الى 2017، لم يلاحظ أي تغيرات في شهري تشرين الاول و تشرين الثاني في قيم الضغط الجوي ولكن في ديسمبر كان هناك ارتفاع نسبي في معظم سنوات الدراسة، معدلات التبخر في ديسمبر بعد عام 2016 كان هناك زيادة نسبية في معدلات التبخر.

الكلمات المفتاحية: الزلازل و التغير المناخي، هطول الامطار، الحرارة، الرياح