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Assessment of Outer Space Events on Troposphere and Climate Change over Iraq

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Abstract

The aim of the study is to investigate the effects of space weather on the troposphere, where our climate exists. This work is useful to give us an idea of the interaction between solar activity and some meteorological parameters. The sunspot number (SSN) data were extracted from the World Data Center for the production, preservation, and dissemination of the international sunspot number (SILSO), top net solar radiation (TSR) and temperature 2 meters from the ERA5 model of the Copernicus Climate Change Service (C3S) from the Climate Data Store with 0.25 grid Resolution, providing a rich source of climate data for researchers. This study was conducted from 2008 to 2021 (solar cycle 24 and the beginning of 25) over Iraq located within latitude (38°N-28°S) and longitude (38°W- 49°E). The results that have been reached were a decrease in solar activity in solar cycle 24, accompanied by an increase in the length of the solar cycles, and there was a direct proportion between TSR and temperature. TSR and temperature had almost similar spatial distribution over Iraq. The northern regions received the least amounts, while from the middle toward the southeast regions, they received the highest amount of TSR and temperature over Iraq. There was a reverse regression between sunspot numbers with TSR and positive regression with temperature, but the correlation was not significant.

Keywords: Sunspots; Troposphere; Solar radiation; Outer space; Solar cycles

تقييم تأثير احداث الفضاء الخارجي على طبقة التروبوسفير وتغير المناخ فوق العراق

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الخلاصة

الهدف من الدراسة هو التحقيق في تأثيرات الفضاء في طبقة التروبوسفير، حيث يوجد مناخنا. هذا العمل مفيد لإعطائنا فكرة عن التفاعل بين النشاط الشمسي وبعض معلمات الأرصاد الجوية، تم استخراج بيانات رقم البقع الشمسية (SSN) من مركز البيانات العالمي لإنتاج وحفظ ونشر رقم البقع الشمسية الدولي (SILSO)،

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(صافي إشعاع شمسي العلوي (TSR) ودرجة الحرارة 2 متر) من نموذج ERA5 لخدمة كوبرنيكوس لتغير المناخ (C3S) من مخزن بيانات المناخ مع دقة شبكة 0.25، حيث يوفر مصدرًا غنيًا لبيانات المناخ للباحثين. أجريت هذه الدراسة من 2008 إلى 2021 (الدورة الشمسية 24 وبداية 25) على العراق الواقع ضمن خط عرض (28S 38N,) وخط طول (38W, E 49). النتائج التي تم التوصل إليها هي ابتداء من الدورة الشمسية 24، كان هناك انخفاض تدريجي في النشاط الشمسي، مصحوبا بزيادة في طول الدورات الشمسية، وهنالك علاقة طردية بين صافي إشعاع شمسي العلوي (TSR) ودرجات الحرارة. TSR ودرجة الحرارة لهما توزيع مكاني متشابه تقريبا على العراق. تلقت المناطق الشمالية أقل الكميات، بينما تلقت المناطق من الوسط إلى الجنوب الشرقي أعلى كمية من TSR ودرجة الحرارة فوق العراق. يوجد انحدار عكسي بين ارقام البقع الشمسية مع صافي الاشعاع الشمسي الكلي وانحدار إيجابي مع درجات الحرارة لكن الارتباط لم يكن كبيرا.

1. Introduction

The sun shows varying degrees of activity. Solar energy reaching Earth is an important contributor to global climate and weather variability. The input of solar energy into the Earth's system is not constant, changes in its amount are caused by three main mechanisms: (1) geometric factors related to the inclination of the Earth's axis and its annual orbit around the sun, (2) processes related to the Earth's system itself (such as albedo, volcanic influences, etc.), and (3) variations in the activity of the sun [1].

Solar variability can be classified as short-term (e.g. solar flares or coronal mass ejections (CMEs), medium-term, and long-term, covering a broad temporal range, from minutes to billions of years. Examples of long-term solar variations include the 11-year Schwabe cycle (sunspot cycle), the 22-year Hale cycle, the 80-90 year Gleissberg cycle, the 180-200 year de Vries cycle, etc [2]. There are many indicators of solar activity: these include sunspot numbers, the solar radio flux at 10.7 cm, and global geomagnetic activity index[3]. Sunspots are areas of strong magnetic field on the Sun's photosphere that appear darker than the surrounding areas and appear as individuals or groups takes ~11 years for each solar cycle to complete , cycle 24 has been considerably weak[4],[5]. This behavior of cycle 24 can affect cycle 25 by providing the sun with less irradiance. Also, numerous studies have mentioned that the low activity of cycle 24 can lead to a global minimum [6].The International sunspot number, RI, is the key indicator of solar activity due to the length of available records. It's given as daily numbers, monthly, yearly averages, and smoothed numbers[7].

Linking the effects of solar activity on climate has been a topic of great interest for many years. It is of great practical importance in terms of distinguishing between natural and anthropogenic causes of climate change. To allow for more reliable estimates of potential future impacts of human activities on climate[4]. One of the main elements mainly used to establish the relationship of the sun to climate and weather was the study of the possible influences of solar activity on various meteorological or climatic parameters in the lower stratosphere and troposphere where we live and make activities and where all atmospheric weather conditions prevail [1],[8].

Solar radiation is energy as electromagnetic radiation released from the sun and penetrates the atmosphere. It is divided into thermal radiation (long wave), visible radiation (light) and short wave radiation [9]. Only one third of the extraterrestrial solar radiation reaches to the Earth's atmosphere [10]. Many factors influence the incident solar radiation, e.g., the terrain, cloud cover, dust storms, and the sun's radiation incidence angle. The dynamics of the Earth's atmospheric processes and climate is driven by this energy and has importance in determining the value of the air temperature by increasing infrared radiation[11]. Temperatures are a form of energy and an important part of climate due to their direct impact on human life or other atmospheric variables such as pressure, humidity, evaporation, etc. The change occurs for natural, human, or external reasons such as solar activities[12], which will be investigated through the effect of sunspots on radiation and temperature.

In 2020, Alabadla, Zaher et al. studied the possible link between sunspots number and estimated solar radiation for a period of five years (2002-2006) over Gaza, Palestine (Latitude 31°25′N, Longitude 34°20′E, and Altitude 14 meters). Linear regression analysis revealed a strong relationship between the variables solar radiation, and sunspot numbers in summer months[13].

In 2021, Mukhtar, M, et al. investigated the relationship between sunspots number and some meteorological parameters (rainfall, solar radiation, maximum temperature, and relative humidity) over Sokoto, of 2008 which represented solar minimum in solar cycle 24. They found a tendency of SSN to drive the commencement of rainfall, solar radiation depicted a very significant relationship with SSN. The maximum temperature showed the likelihood of been influenced by the SSN at the solar minimum while the relative humidity was found to establish a relatively significant correlation at the solar minimum[8].

2. Methodology

This study was conducted in the region of Iraq located within latitude (38°N-28°S) and longitude (38°W- 49°E). SSN data employed in this paper was supplied by the World Data Center for the production, preservation, and dissemination of the International Sunspot Number (SILSO)[14]. In addition, the monthly average data at 12 pm which represented the peak of the TSR and the temperature of 2 meters, were taken from the Copernicus Climate Change Service (C3S) ERA5 model from the Climate Data Store with 0.25 grid resolution[15]. For the14-year period from 2008 to 2021 (solar cycle 24 & beginning of 25).

The data were processed with Matlab software, the calculations were performed in Excel and the time series plots were applied by Sigmaplot. Two-dimensional contour maps of monthly and annual averages of the TSR and temperature over Iraq were also applied using the Surfer program. A simple linear regression (R) was applied to examine the relationship between SSN and climate parameters (TSR and temperature), described in the following equation:[12]

$$\bar{Y} = a + b\bar{X} \tag{1}$$

$$b = \frac{\sum_{i=1}^{n}(Xi-\bar{X})-(Yi-\bar{Y})}{\sum_{i=1}^{n}(Xi-\bar{X})^2} \tag{2}$$

Where: (a) cut off on y-axis, (b) slop of regression, ($\bar{Y}$) dependent variable, ($\bar{X}$) independent variable, and (n) number of data.

The square of the regression coefficient, known as the coefficient of determination (R^2) is the most commonly used measure to describe the extent to which the dependent variable is influenced by the independent variable. It falls between 0, no effect, and 1, the strongest effect[12].

3. Results and discussion

The results of the study are presented in several sections: the concept of the solar cycle, the clarification of the relationship between TSR and temperature, and finally the relationship of sunspots with TSR and temperature.

3 .1 Solar Cycle

Figure 1 shows the last five solar cycles recorded from the monthly mean and monthly smoothed values of observed sunspots on the sun. The figure shows the general behavior of the solar cycles, as a solar cycle is completed every 10 to 13 years, and a gradual decrease in the activity of the solar cycles beginning with cycle 21 to cycle 24, which represented the lowest values of the cycles, and this decrease was accompanied by an increase in the length of the cycle.

Figure 2 shows the daily and monthly smoothed SSN for solar cycle 24 and the beginning of 25, which represents the period of study. Solar cycle 24 began in 2008 and ended in 2019 to start solar cycle 25. These cycles contained many areas of maximum and minimum solar activity, where the lowest activity was in 2008 and 2020 as this marked the end of a cycle and the beginning of a new cycle due to the decrease of the number of sunspots in the solar disk, while the highest activity was in 2012 and 2014, which represented the maximum of the solar activity due to the increase of sunspot number in the solar disk.

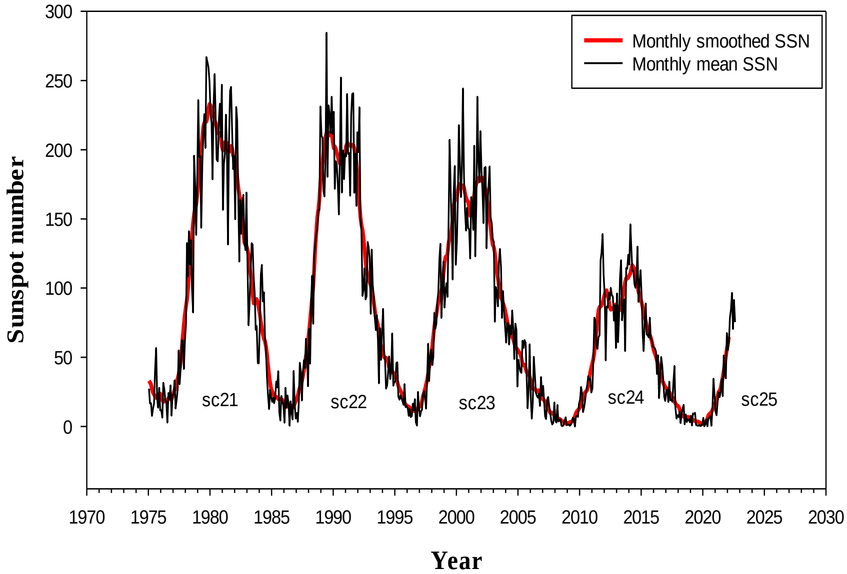


Figure 1: International sunspot number: last five solar cycles.

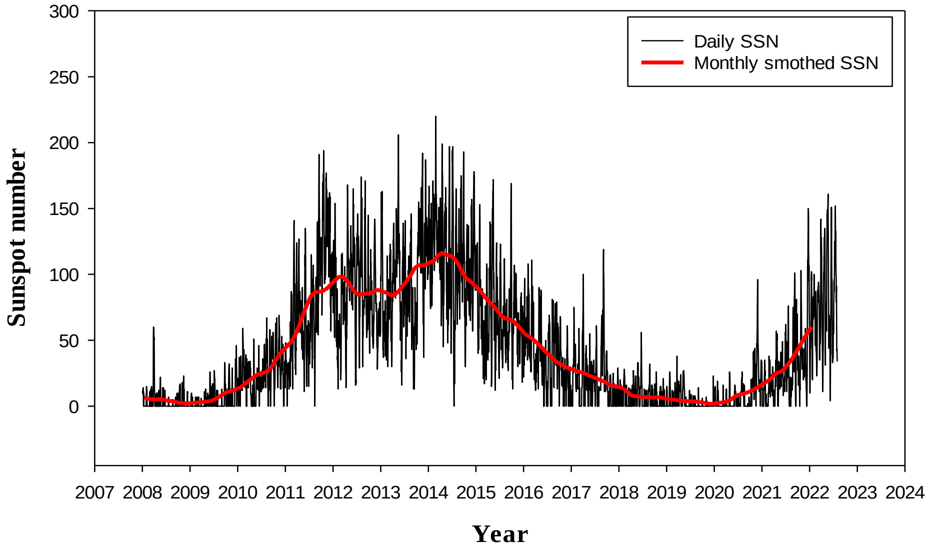


Figure 2: Daily and monthly smoothed sunspot number for solar cycles 24&25.

3 .2 Top net solar radiation and temperature

This section investigates the relationship between TSR and temperature over Iraq from 2008 to 2021. Figure 3 presents the monthly average of TSR and temperature for (2008-2021). The general behavior of TSR and temperature showed a positive correlation. The value of TSR started in January 415 wh/m^2, then gradually increased until it reached the highest value in June 828wh/m^2 and decreased again to the lowest value in December 363wh/m^2. While the temperature 13°C in January was the lowest value, then gradually rose to 40°C in July the highest value and dropped again to 15°C in December. This is due to the Earth's axis of rotation around the sun and oscillation.

The relationship between annual average of TSR and temperature over Iraq for (2008-2021) shows in figure 4. When TSR was high in 2010, temperature had the same behavior as their rise, and when TSR decreased in 2018-2019 and 2020 the temperature also decreased. It appears that the relationship is strong, but not completely direct because TSR is the main factor that supplies the atmosphere with temperature, but in indirect ways, depending on the conduction, convection, the geographical nature of the area, and the transmission of wind, as the air is a weak conductor.

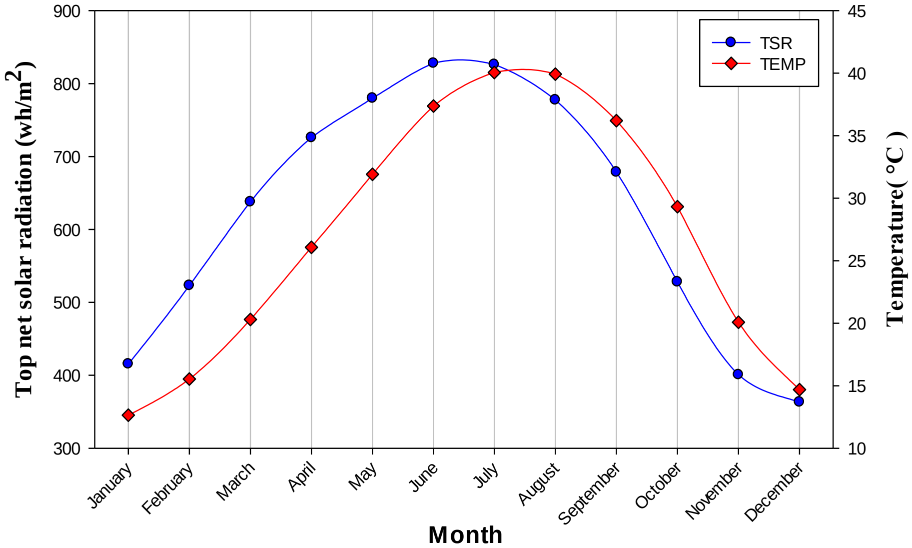


Figure 3: The monthly averages of top net solar radiation and temperature 2 meters over Iraq from 2008 to 2021.

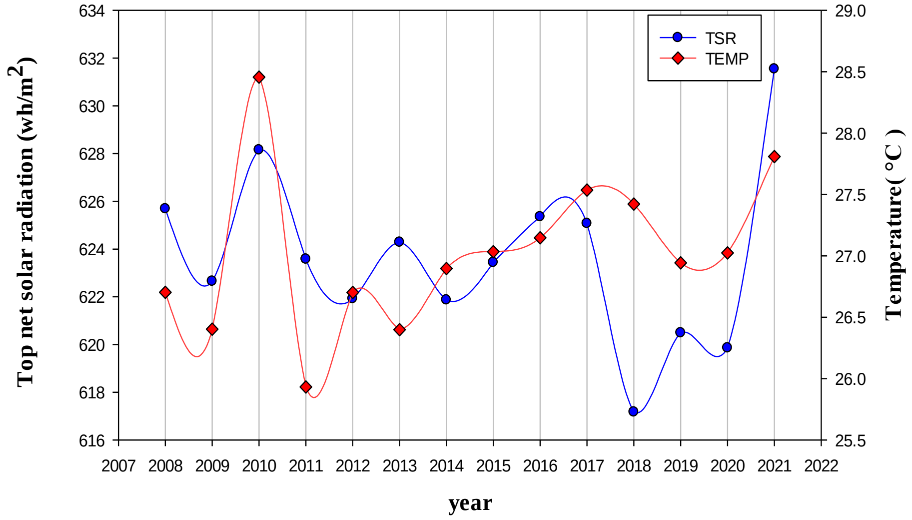


Figure 4: The annual average of top net solar radiation and temperature 2 meters over Iraq from 2008 to 2021.

Contour maps were made for the monthly average of TSR and temperatures of (2008-2022), the purpose of which is to examine the spatial distribution of TSR and temperature over Iraq. Figure 5 shows TSR, the lowest recorded value of TSR was 222 wh/m^2 in December, and the highest value was 1023 wh/m^2 in July. Figure 6 shows the monthly averages of temperature where the values were between -5°C in January to 48°C in July. The northern regions had the lowest TSR and temperature monthly averages, from the middle towards the southeast had the highest TSR and temperature as a result of the fact that the southern regions are closer to the Earth's equator, they receive more TSR than the northern regions, which are farther away.

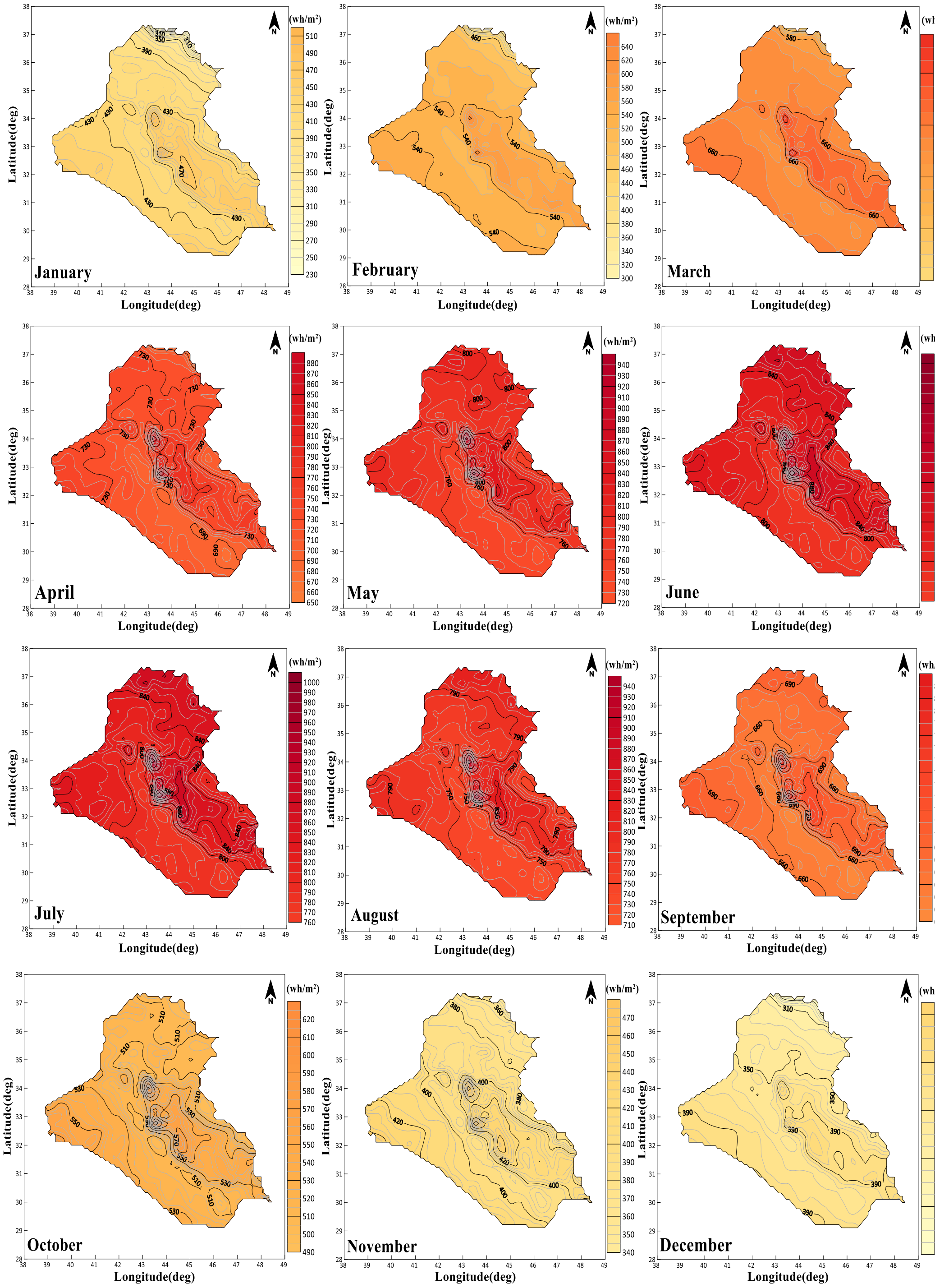


Figure 5: The monthly average of top net solar radiation over Iraq from 2008 to 2021.

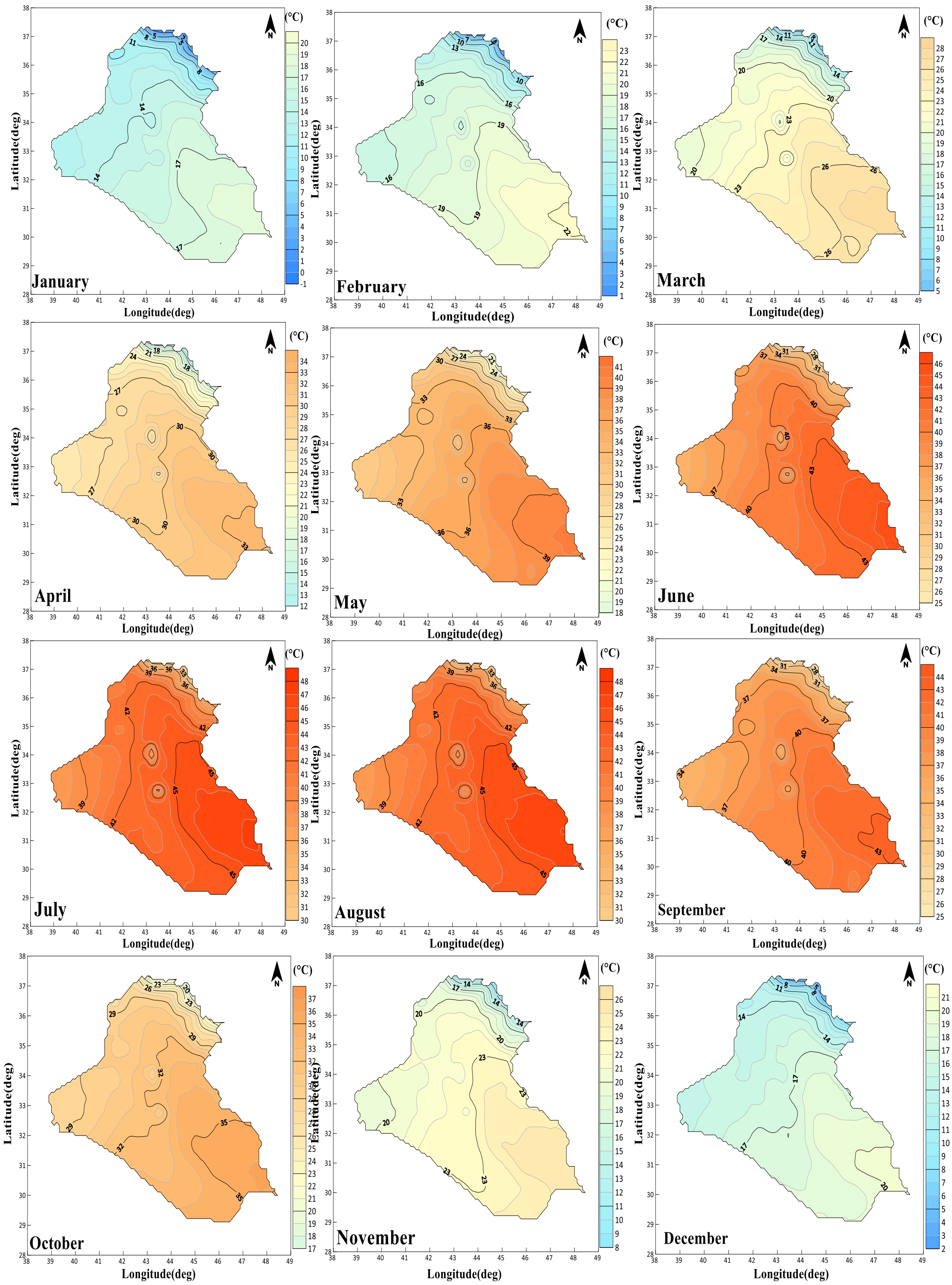


Figure 6: The monthly average of temperature 2 meters over Iraq from 2008 to 2021.

3 .3 Sunspot Number with Top Net Solar Radiation and Temperature

Examining the relationship between sunspots and meteorological parameters (TSR and temperature), Figures 7 and 8 represent the annual average of TSR and temperature over Iraq, respectively, with SSN from 2008 to 2021. The highest TSR values were in 2010 and 2021, and the lowest were in 2018 and 2020. For temperatures, the highest activity was in 2010 and 2021, while the lowest was in 2011.

Figure 9 represents the relationship between the monthly average of sunspot numbers with (a) top net solar radiation, and (b) temperature from 2008 to 2021 over Iraq. (a) shows an inverse relationship between SSN and TSR with R^2 = 0.138, (b) shows a positive relationship between SSN and temperature with R^2 =0.00541, that is, the relationship between SSN with TSR and temperature is not significant.

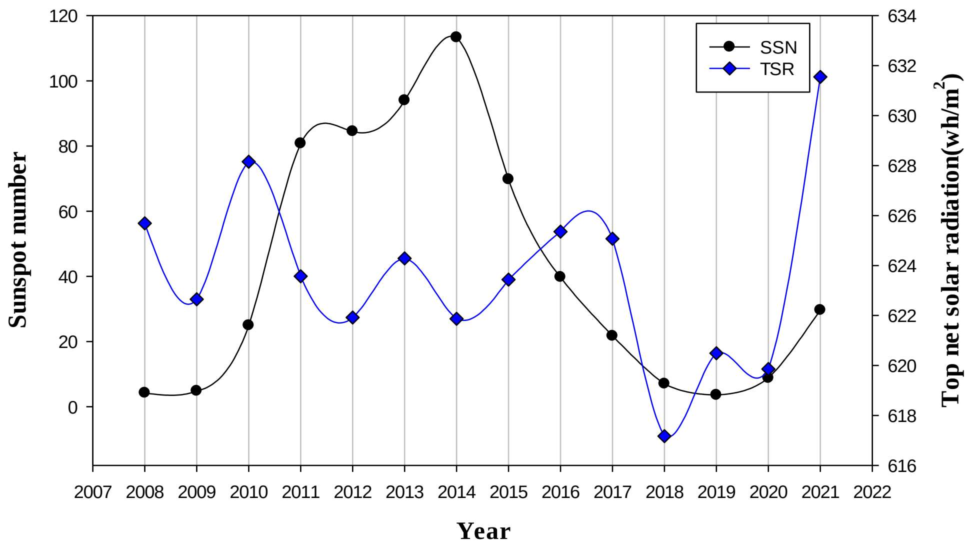


Figure 7:The annual average of international sunspot numbers &top net solar radiation over Iraq from 2008 to 2021.

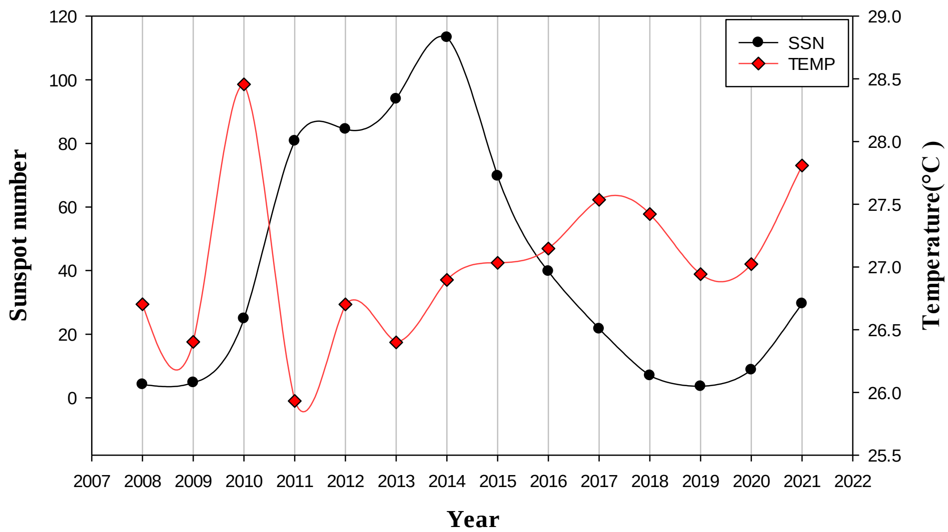


Figure 8: The annual average of international sunspot numbers &temperature 2 meters over Iraq from 2008 to 2021.

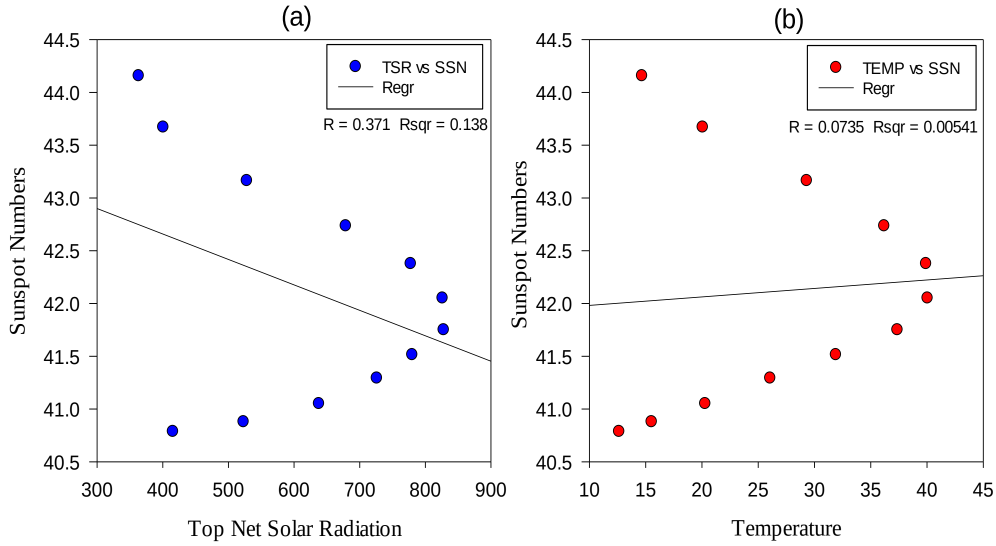
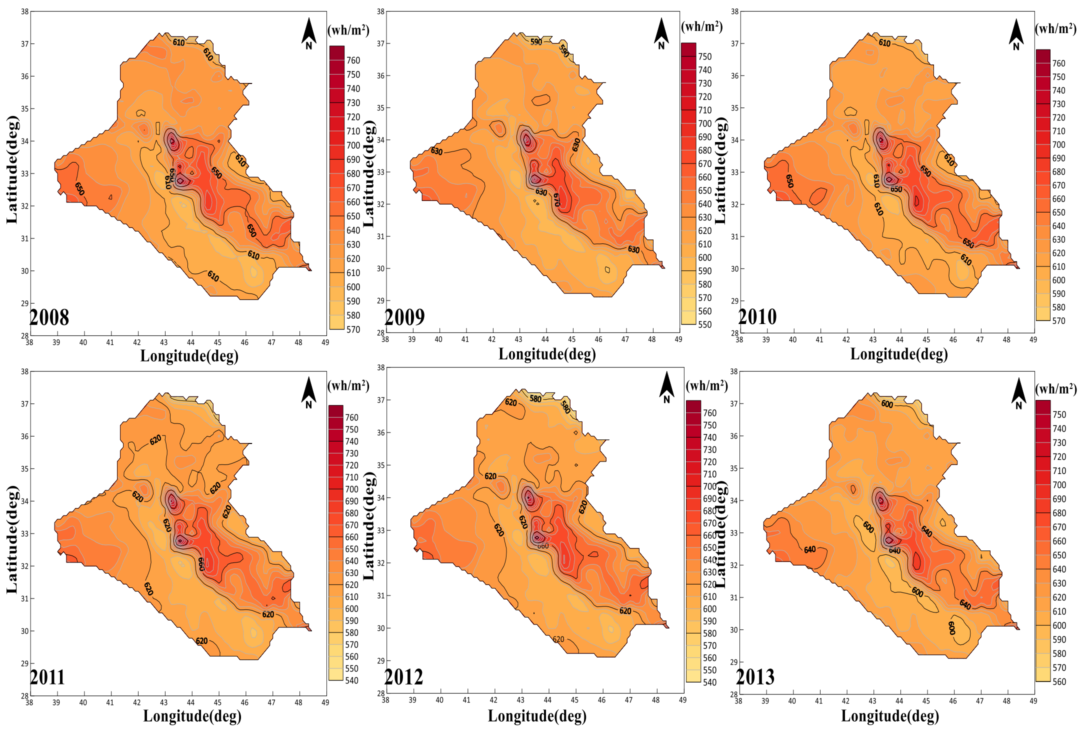


Figure 9: The relationship between the monthly average of sunspot numbers with top net solar radiation (a), with temperature (b) from 2008 to 2021 over Iraq.

Figure 10 shows the annual average of TSR over Iraq of (2008 to 2021). Figure 11 shows the annual average of temperature 2 meters over Iraq of (2008 to 2021). Iraq's climate did not witness a noticeable change in terms of TSR and temperature from 2008 to 2021. Where the annual TSR average ranged between the lowest average 617 Wh/m^2 in 2018 and the highest average 631wh/m^2 in 2021. As for temperatures, the annual average of temperatures was between the lowest average of 26°C in 2011 and the highest average of 28°C in 2010. For the spatial distribution, from the middle towards the southeast received highest annual average of TSR and temperature, while upper regions received lowest average of TSR and temperature.

The regions from the west had a high annual average of TSR, which did not show up in the temperature because these regions have large amounts of rain and humidity (which have inverse relationship with temperature) compared to other regions.


2008
2009
2010
2011
2012
2013
Latitude(deg)
Longitude(deg)
(wh/m²)
N

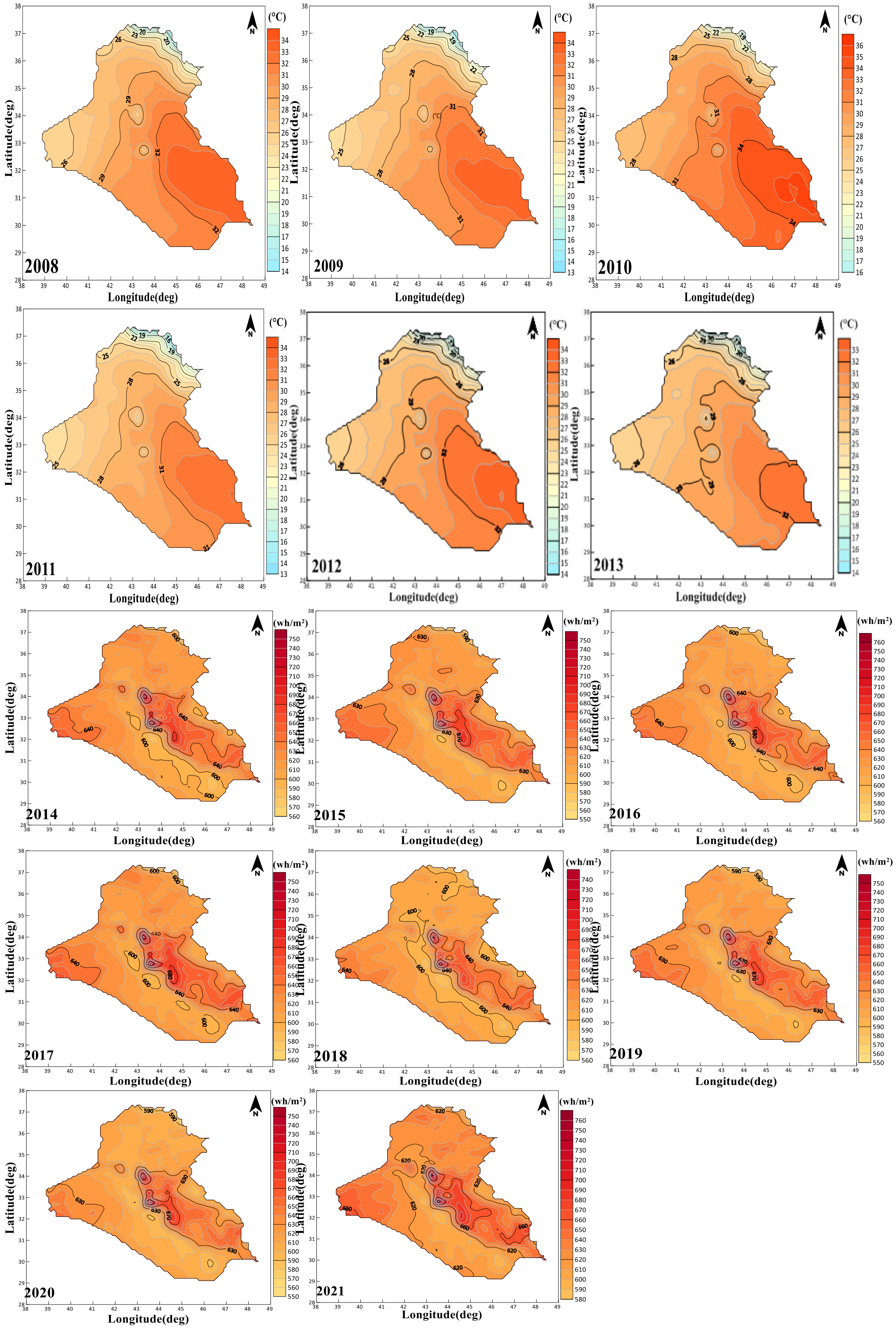


Figure 10: The annual average of top net solar radiation over Iraq from 2008 to 2021.

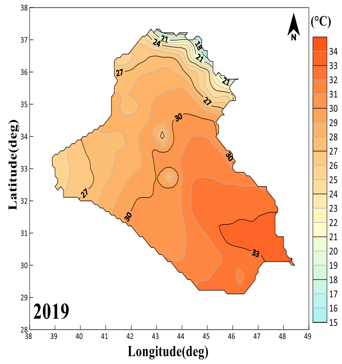
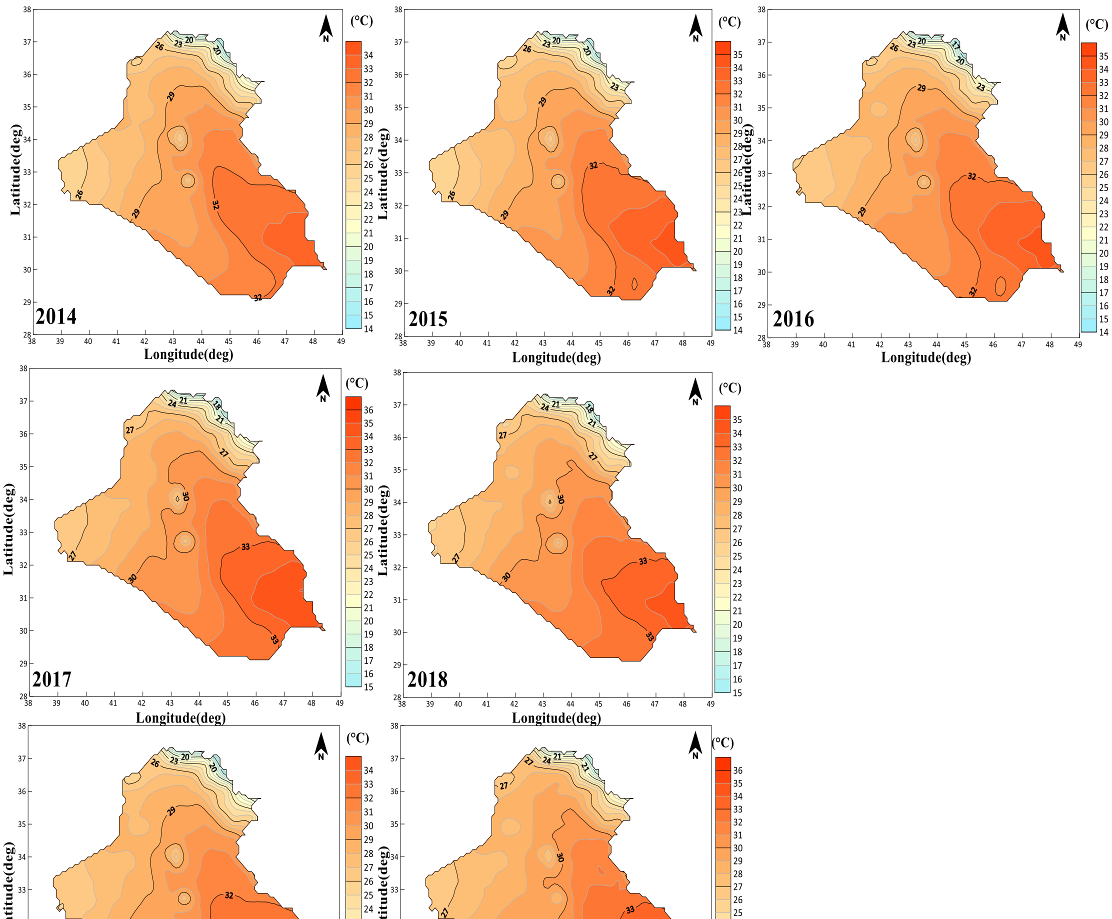


Figure 11: The annual average of temperature 2 meters over Iraq from 2008 to 2021.



4. Conclusion

The results of this analysis are summarized as the following: there was a decrease in solar activity in solar cycle 24, accompanied by an increase in the length of the cycle. Solar cycle 24 started in December 2008 and ended in December 2019, reached its maximum in 2012 and 2014, and had less activity than the previous cycle 23.

TSR and temperature have a direct proportion: the highest monthly average of TSR was in June, while the lowest was in December. The highest monthly average of temperature was in July, while the lowest was in January. For spatial distribution, the northern regions of Iraq received the least monthly averages of TSR and temperature, while middle regions toward the southeast received highest monthly averages of TSR and temperature. The annual TSR average ranged between the lowest average in 2018 and the highest average in 2021. The annual average of temperatures was between the lowest average in 2011 and the highest average in 2010.

There is no significant correlation between SSN with TSR and temperature in the troposphere for solar cycles 24 and 25. SSN shows a reverse regression with TSR and a positive regression with temperature.

It may be useful to extend the study period to include more solar cycles and study other meteorological parameters to understand the interaction between the solar activity with the components of the atmosphere, which will be considered in later studies.

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