Al-Mustansiriyah Journal of Science
ISSN: 1814-635X (print), ISSN:2521-3520 (online)   Volume 33, Issue 2, 2022   DOI: http://doi.org/10.23851/mjs.v33i2.1174

Research Article   Open Access

The Effect of Solar Activity on Stratospheric Temperature Over Iraq for Period 1948-2014

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Article Info

Received
20/09/2021

Accepted
28/11/2021

Published
30/06/2022

ABSTRACT

Stratospheric temperature changes are very important for climate systems through atmospheric circulation and stratosphere-troposphere coupling. The relationship between solar modulation potential SMP as a measure of solar activity and variation of temperature in upper, middle and lower stratosphere over Iraq for the period 1948-2014 (for about five solar cycles) has been presented in this study. For upper, middle and lower stratosphere we found that stratospheric temperatures decreased, this descending trend is offset by obviously descending trend in solar activity for the same period. The correlation coefficients between annual solar modulation potential SMP and stratospheric temperature have been examined at pressure levels (10,20,30,50,70 mb) that represent the upper, middle and lower stratosphere over 67 years (1948 to 2014). All levels have positive correlation. The correlation coefficient (R) in upper stratosphere at level 10 mb has been 0.4, in middle stratosphere at level (20, 30 mb) the correlation coefficient (R) has been 5.3 and 0.6 respectively. For lower stratosphere at level (50, 70 mb) R has been 0.57 and 0.68 respectively.

KEYWORDS: Solar activity; solar modulation potential; stratospheric temperature; climate change.

الخلاصـة

يلعب التغير الحاصل في درجة حرارة طبقة الستراتوسفير دور مهم جدا في تحديد الانظمة المناخية، وذلك من خلال الدورة العامة للغلاف الجوي والتأثير المتبادل بين طبقتي الستراتوسفير– التروبوسفير. في هذه الورقة البحثية تم دراسة العلاقة بين الحرارة الكامنة او الجهدية للشمس SMP كمقياس للنشاط الشمسي (لما يقارب خمس دورات شمسية) وبين التغيرات الحاصلة في درجات الحرارة في اعلى ، أوسط واسفل طبقة الستراتوسفير فوق العراق للفترة الزمنية 1948- 2014. وجدت الدراسة ان هنالك تناقص في درجات حرارة اعلى، وسط واسفل طبقة الستراتوسفير متزامنا مع التناقص الواضح في النشاط الشمسي لنفس الفترة الزمنية. تم استخراج معاملات الارتباط (R) بين SMP وبين درجات الحرارة للمستويات الضغطية (10،20،30،50،70) ملي بار والتي تمثل اعلى ، وسط واسفل طبقة الستراتوسفير على مدى 67 عاما (1948-2014)، وقد كانت العلاقة طردية لجميع المستويات حيث كانت R= 0.4 عند المستوى الضغطي 10 ملي بار (الستراتوسفير العلوي)، بينما كانت قيم R في وسط طبقة الستراتوسفير عند المستويين الضغطيين (20،30) ملي بار هي 5.3 و 0.6 على التوالي. اما في اسفل الستراتوسفيرعند المستويين الضغطيين (50،70) ملي بار فكانت قيم R هي 0.57 و0.68 على التوالي.

INTRODUCTION

Billions of years ago, the sun emitted radiation and charged particles to the Earth

and the rest of the solar system’s components. The Earth's climate may be the result of solar activity changes during successive solar cycles. The atmosphere consists of gases in almost constant proportions, and the apparent increase of one of these gases leads to an imbalance in the chemical composition of the atmosphere. The increase in solar activity has led the atmosphere to receiving more quantities of radiation, especially ultraviolet radiation, and this means an increase in ozone production and thus heating the stratosphere. Also, the decrease in the intensity of solar activity has led the atmosphere to receive lees quantities of solar radiation and this means a decrease in stratospheric temperature or it has led to cooling atmospheric.

During the past decade, many studies have been addressed on the effect of solar activity on the climate, and despite most of these studies, no definite fact has been revealed that there is a clear relationship between them, but it is necessary to intensify such studies to understand the nature and mechanism of this relationship.

For example, Claud and et al. (2008), has been shown that there is a response to temperatures in the lower stratosphere with the ~11years solar cycle, this response is evident during seasonal and monthly changes, especially in the mid and lower northern latitudes [1]. Minimum solar activity leads to stratosphere cooling at ~ 1 hpa in an average annual global about 1.5 kelvin and decrease average annual global near surface temperature about 0.1 kelvin. The relationship between sunspots as an indicator of solar activity and sea level temperatures for 111 years has been studied by Yamakawa *et al*., (2016), and the results have been a significant positive correlation between them, and that solar activity has an important impact on stratosphere and troposphere temperatures [3]. The thermodynamic processes of the large scale are correlated with reliable statistical relationships with temperatures changes in the stratosphere and troposphere during ~11year solar cycle [4].

The aim of this work, first, is to determine a solar activity index more clearly and reliably than the rest of the indicators and use it in this study. Secondly, attempt to find a statistical correlation between solar activity and stratosphere temperatures at the pressure levels (10,20,30,50,70 mb) of Iraq for the period 1948-2014.

DATA AND METHODOLOGY

In this work, we used the global monthly temperature (°C) for the period 1948-2014 as given by NOAA/ESRL Physical Sciences Division (PSD) dataset (https://www.esrl.noaa.gov) in a $2.5^0 \times 2.5^0$ geographical grid. The monthly temperature (0C) data over Iraq, separated from global monthly temperature (°C) data at the location 30ºN - 37ºN, 40 ºE -47 ºE for levels (10,20,30,50,70 mb) in 1948−2014 (Figure 1) by the widely known package Climate Data Operators (CDO). The monthly values of galactic cosmic rays (GCR) from 1983 to 2009 recorded by ground-based neutron monitors (NMs) is situated in Northern Finland from Oulu neutron monitor dataset used in this paper. And also, the monthly sunspot numbers (SSN) data at 1983-2009 as given by National Centers for Environmental Information has been used. (https://www.ngdc.noaa.gov). Also, the monthly values of Solar Modulation Potential (SMP) have been used during 19-23 solar cycles for period 1948-2014 from Al-Tameemi and Chukin, (2016). The SMP is a solar activity indicter, it is considered the most reliable among the other indicators. [5]. In fact, the effect of solar activity (11 years solar cycles) on stratospheric temperature, also changes with altitude (Huang, F. T., Mayr, H. G (2019) according the local time of measurement (due to diurnal variation over 24 hours or in sunrise and sunset) and it's also changing according to the latitude. The effects of diurnal solar cycles on temperature are not trivial even at altitude 30 km and above, but it can be significant at altitude from 50 to 100 km [6, 7].

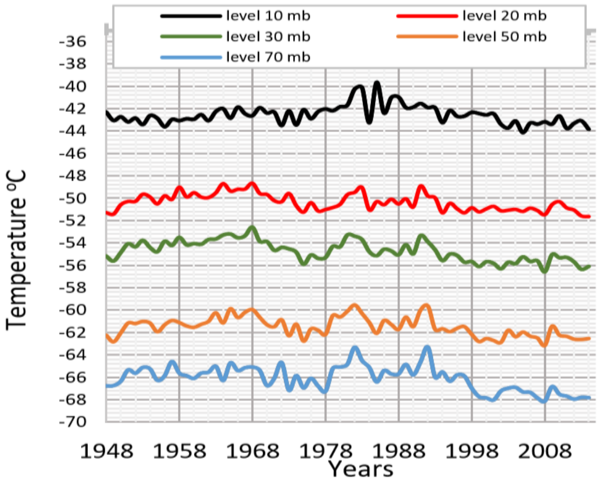

Figure 1. Time series of monthly temperature (°C) over Iraq for the period 1948-2014. Level 10 mb (black), level 20 mb (red), level 30 mb (green), level 50 mb (orange) and level 70 mb (blue).

The relation between Sunspot Number (SSN) and GCR for the period 1983−2009 in Figure 2a and Figure 2b represents the relation between SMP and GCR during the same period (1983-2009) with a correlation coefficient of -0.8 as shown in Figure 3. Although the correlation between the GCR and SMP, is not completely identical, the SMP parameter is used here because it has a clear physical explanation and can be used by numerical models as an input parameter.

RESULTS AND DISCUSSION

In this work. firstly, The SMP parameter has been identified as a solar activity indicator, and then it has been used for testing. Statistical analysis has been performed to find out the relationship between SMP and monthly stratospheric temperature over Iraq for the period 1948-2014 for five pressure levels

ISSN: 1814-635X (print), ISSN:2521-3520 (online) Volume 33, Issue 2, 2022 DOI: http://doi.org/10.23851/mjs.v33i2.1174

(10,20,30,50,70 mb) which can be represented the different stratospheric levels from top to bottom as follows: level (10 mb) represents the upper-stratosphere, levels (20 and 30 mb) represent the middle-stratosphere and levels (50 and 70 mb) represents the lower-stratosphere.

(a)

(b)

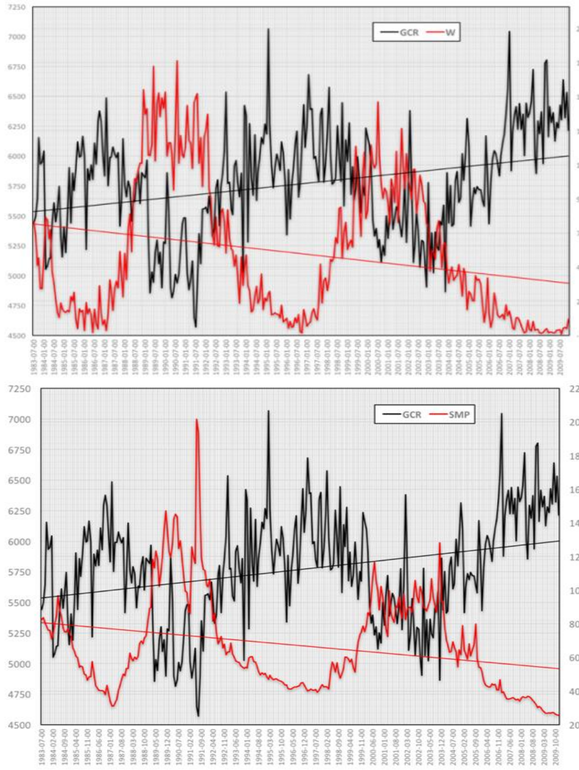

Figure 2. (a) Relation between SSN and the GCR for the period 1983−2009, (b) relation between the GCR and the SMP for the period 1983−2009.

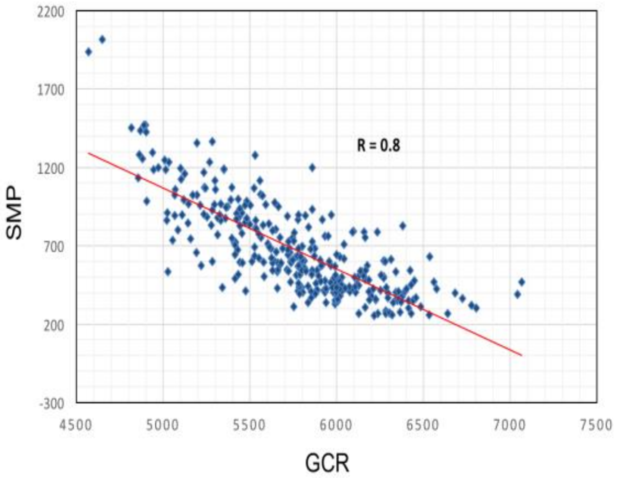

Figure 3. Correlation between GCR and SMP for the period 1983-2009.

The trend of annual stratospheric temperature variation for levels (10,20,30,50,70 mb) with trend of monthly SMP variation are shown in Figures (4,6,8,10,12). for upper, middle and lower stratosphere, it can be found that the temperatures decreased over the course of 67 years (19-23 solar cycles), this descending trend is offset by obviously descending trend in solar activity for the same period. The annual change of temperature in upper-stratosphere is large (~ -1 °C) over 67 years it's larger than annual change of temperature in meddle and lower stratosphere it has been (~ -0.7 °C).

It can also be noted that during each solar cycle there is a clear response for stratospheric temperatures changes with solar activity changes, whether minimum or maximum solar activity. At upper-stratosphere, there is an unclear response of stratospheric temperature changes with SMP for all the solar cycles under study except for the solar cycle 21 which has a clear response signal. Sub-tropical regions have a positive response of temperature changes in the upper stratosphere to solar activity changes, but they are not sufficiently understood [8]. in the middle and lower stratosphere, temperatures show a clear response to changes in solar activity, especially for solar cycles (20,21 and 22), which have not been strong solar cycles, while the temperature response to changes in solar activity has been irregular for solar cycle 19 which is more active than solar cycles (20,21 and 22). In the middle-stratosphere and lower-stratosphere and troposphere, temperatures do not show a uniform response when the sun is more active, especially in lower latitudes and subtropics to middle latitudes around the world [9].

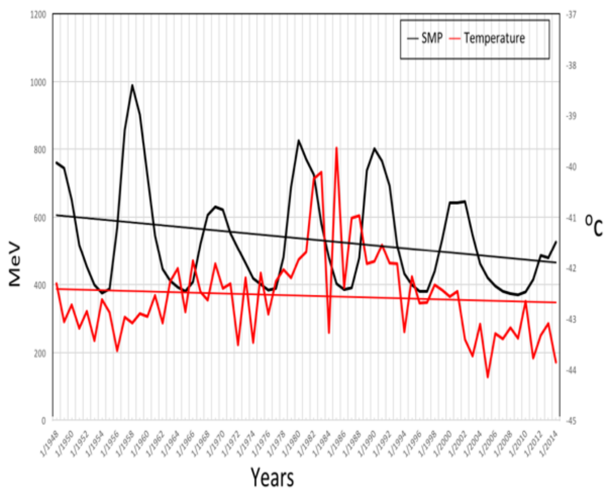

Figure 4. The trend of annual stratospheric temperature variation for level 10 mb with trend of annual SMP variation in 1948-2014 over Iraq.

Figures 5-13 shows a positive correlation between temperature at levels (10,20,30,50,70 mb) and SMP in 1948-2014 over Iraq, respectively. We estimated correlation coefficient by the Student's T-Test at level of significance (0.05). At upper stratosphere Figure 5 the correlation coefficient has been 0.4, as mentioned before that the relation between temperature at upper stratosphere and solar activity has not been clear in sub-tropical regions. In middle-stratosphere at levels (20,30 mb) shown in Figures 7, 9 the correlation coefficient has been (0. 54 and 0.6) which is bigger than it at upper stratosphere. In lower stratosphere at level, 50 mb the correlation coefficient has been (0.57) see Figure 11 and at level, 70 mb is (0.68) as shown in Figure 13.

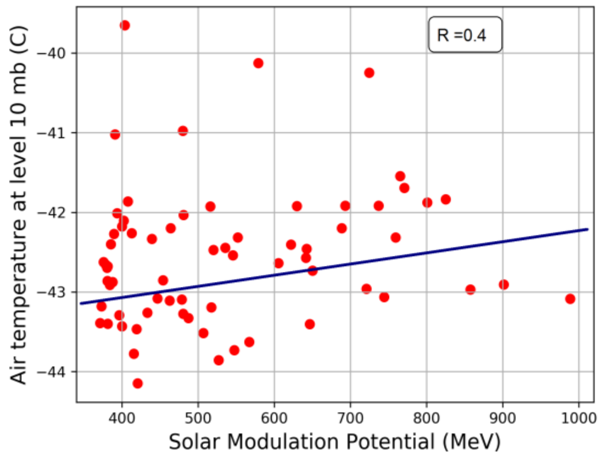

Figure 5. Correlation between temperature for level 10 mb and SMP for the period 1948-2014 over Iraq.

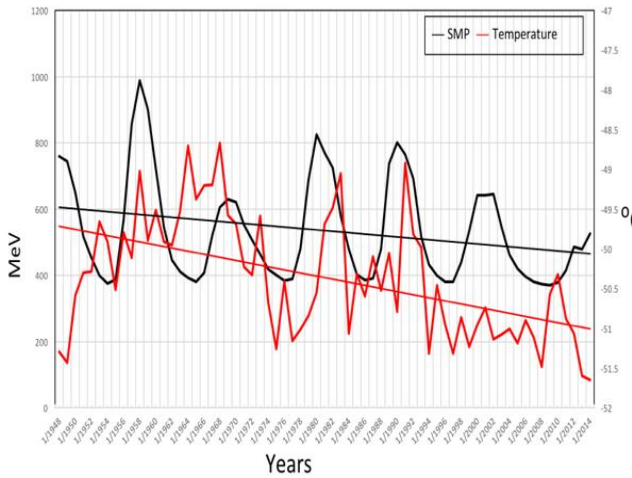

Figure 6. The trend of annual stratospheric temperature variation for level 20 mb with trend of annual SMP variation in 1948-2014 over Iraq.

Depending on the results, the greatest correlation has been between the temperature and the solar activity at lower stratosphere and the lowest correlation at upper stratosphere. The results above can be considered as a good correlation even though they are not strong. This is because solar activity is not the only force that control stratospheric temperatures, but there are five additional forces that affect the temperatures in the stratosphere, these are: the regular seasonal cycle mechanism, effects of El Niño-Southern Oscillation (ENSO), the semiannual zonal wind oscillation (SAO) at higher levels, the quasi-biennial oscillations (QBO) in zonal winds and finally the radiative impacts, including heating by volcanic aerosol [10].

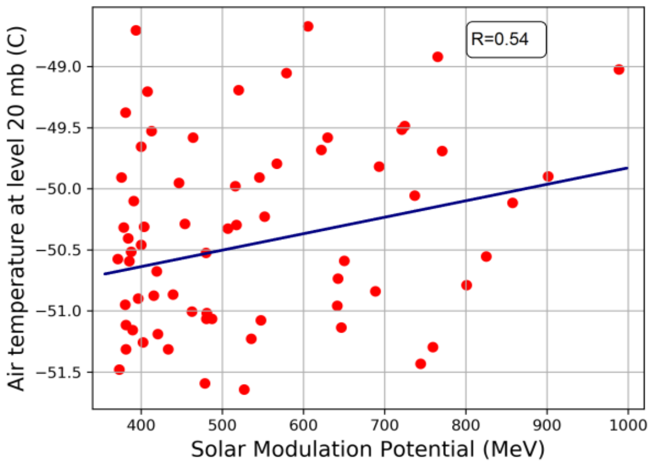

Figure 7. Correlation between temperature for level 20 mb and SMP for the period 1948-2014 over Iraq.

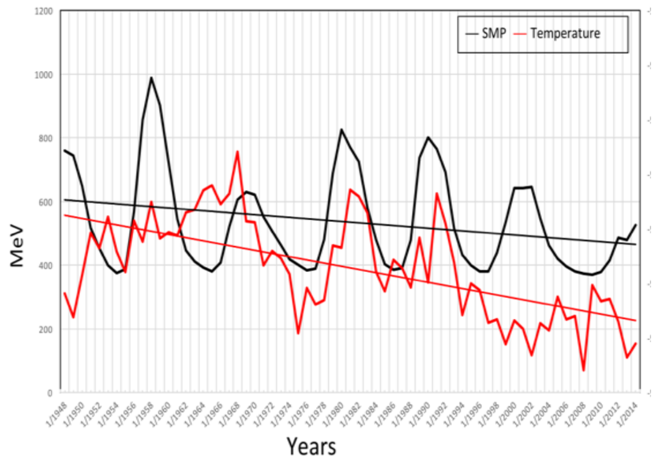

Figure 8. The trend of annual stratospheric temperature variation for level 30 mb with trend of annual SMP variation in 1948-2014 over Iraq.

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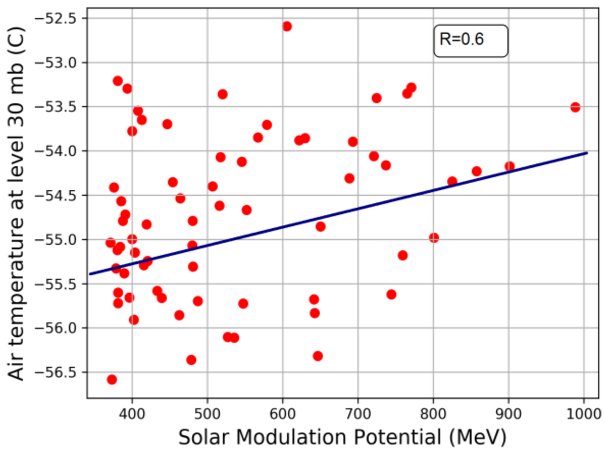

Figure 9. Correlation between temperature for level 30 mb and SMP for the period 1948-2014 over Iraq.

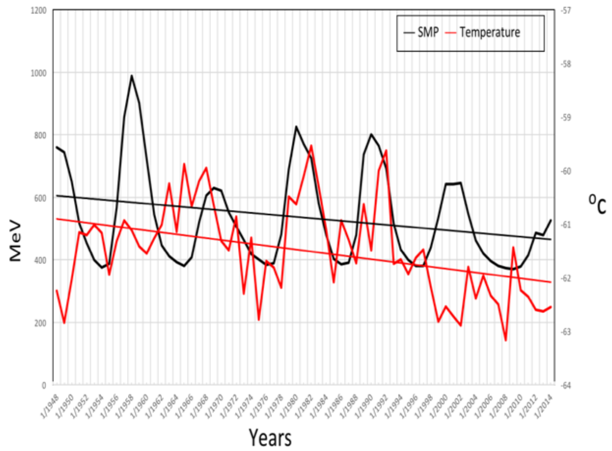

Figure 10. The trend of annual stratospheric temperature variation for level 50 mb with trend of annual SMP variation for the period 1948-2014 over Iraq.

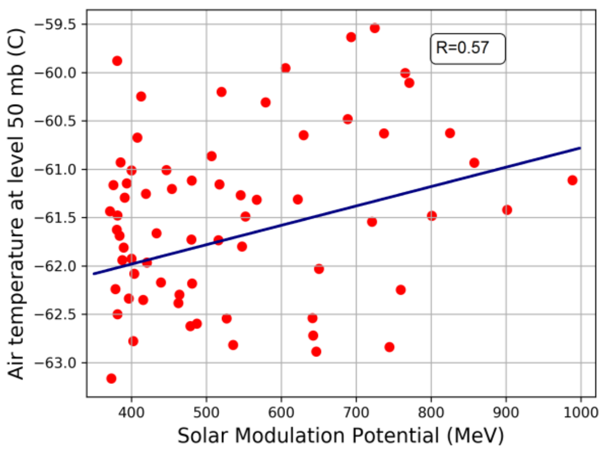

Figure 11. Correlation between temperature for level 50 mb and SMP in 1948-2014 over Iraq.

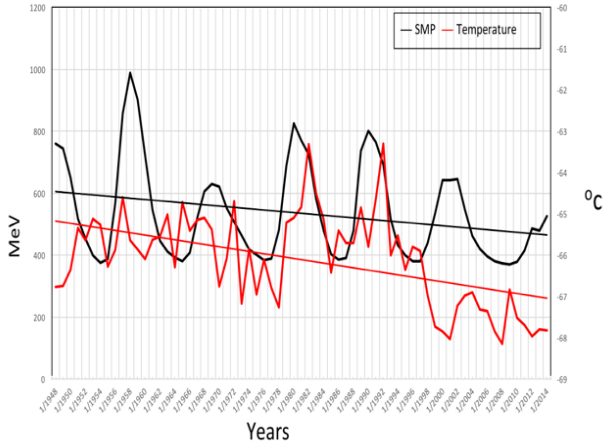

Figure 12. The trend of annual stratospheric temperature variation for level 70 mb with trend of annual SMP variation for the period 1948-2014 over Iraq.

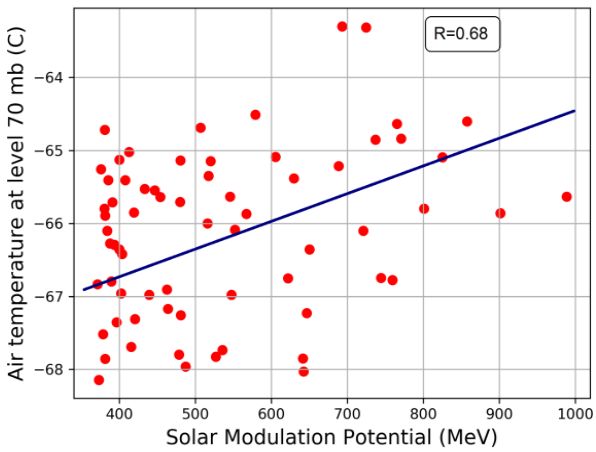

Figure 13. Correlation between temperature for level 70 mb and SMP for the period 1948-2014 over Iraq.

CONCLUSIONS

An analysis of the relationship between SMP as a measure of solar activity and variation of temperature in upper, middle and lower stratosphere over Iraq in 1948-2014 (19-23 solar cycles) has been conducted in this study using statistical analyses. The results are summarized as follows:

The annual change of temperature in upper-stratosphere is large (~ -1 ºC) over 67 years its larger than the annual change of temperature in meddle and lower stratosphere that has been (~ -0.7 ºC).

During each solar cycle, there is a clear response for stratospheric temperatures changes with solar activity changes, whether minimum or maximum solar activity.

For upper, middle and lower stratosphere we can find out that the temperatures decreased in 1948-

2014, this descending trend is offset by obviously descending trend in solar activity for the same period.

All levels have positive correlation between SMP and temperature. in upper stratosphere at level 10 mb it has been 0.4 in middle stratosphere at level (20, 30 mb) is R= 5.3 and R=0.6 respectively. for lower stratosphere at level (50,70 mb) it has been (R=0.57 and R=0.68) respectively.

REFERENCES

[1] Claud, Chantal, Chiara Cagnazzo, and Philippe Keckhut. "The effect of the 11-year solar cycle on the temperature in the lower stratosphere." Journal of atmospheric and solar-terrestrial physics 70.16 (2008): 2031-2040.

[2] Maycock, A. C., et al. "Possible impacts of a future grand solar minimum on climate: Stratospheric and global circulation changes." Journal of Geophysical Research: Atmospheres 120.18 (2015): 9043-9058.

[3] Yamakawa, Shuji, Makoto Inoue, and Ramasamy Suppiah. "Relationships between solar activity and variations in SST and atmospheric circulation in the stratosphere and troposphere." Quaternary International 397 (2016): 289-299.

[4] Gruzdev, A. N. "Variations in the temperature and circulation of the atmosphere during the 11-year cycle of solar activity derived from the ERA-Interim reanalysis data." Izvestiya, Atmospheric and Oceanic Physics 53.4 (2017): 441-448.

[5] Al-Tameemi, Muthanna A., and Vladimir V. Chukin. "Global water cycle and solar activity variations." Journal of Atmospheric and Solar-Terrestrial Physics 142 (2016): 55-59.

[6] Huang, F. T., Mayr, H. G. "Ozone and temperature decadal solar cycle responses, and their relation to diurnal variations in the stratosphere, mesosphere, and lower thermosphere, based on measurements from SABER on TIMED" Ann. Geophys., 37, 471-485,2019.

https://doi.org/10.5194/angeo-37-471, 2019.

[7] Huang, F. T., Mayr, H. G., Russe III, J. M., and Mlynczak, M. " Ozone and temperature decadal responses to solar variability in the mesosphere, and lower thermosphere, based on measurements from SABER on TIMED" Ann. Geophys., 34, 29-40,

https://doi.org/10.5194/angeo-34-29-2016, 2016a

[8] Keckhut, Philippe, et al. "The 11-year solar-cycle effects on the temperature in the upper-stratosphere and mesosphere: Part I—Assessment of observations." Journal of atmospheric and solar-terrestrial physics 67.11 (2005): 940-947.

[9] Christiansen F., Joanna D. and Lundstedt H. "Influence of Solar Activity Cycles on Earth’s Climate." Danish National Space Center Scientific Report 2(2007): 2007.

[10] Reid, George C. "Seasonal and interannual temperature variations in the tropical stratosphere." Journal of Geophysical Research: Atmospheres 99.D9 (1994): 18923-18932.

How to Cite

M. A. . Al-Tameemi, B. J. . Hassan, and A. G. . Mutar, “The Effect of Solar Activity on Stratospheric Temperature over Iraq for Period 1948-2014”, *Al-Mustansiriyah Journal of Science*, vol. 33, no. 2, June 2022.