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Investigating a solar activity effect on cloud cover over Baghdad city

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Abstract

Cloud cover is an important factor controlling the way that radiation is absorbed and reflected by the earth. Increases in cloudiness enhance global albedo, thus tending to cool the surface and the effect on earth's radiation characteristics and the climate in general, thus tending to global warming and climate changes.

In this work, is an attempt to investigate and understand the impact of solar activity on cloud cover amount over Baghdad city in 1983-2009 by analyzing the monthly values of cloud cover amount (low, mid-level, high and total), galactic cosmic rays, and the solar Modulation potential in 1983−2009, and use package Climate Data Operators for this purpose.

The first object of this study was to determine the solar activity index (the Solar Modulation Potential SMP) instead of (galactic cosmic rays GCR), SMP was selected as an indicator of solar activity with a correlation coefficient (0.8) with GCR. The second object of our study was to investigate the relationship between the solar modulation potential (solar activity index) and cloud cover amount over Baghdad city for the period 1983−2009. The results showed that there is a relationship between the solar modulation potential and cloud cover amount for the period of study with the highest coefficient of correlation was (R= -0.71 ± 0.22) between total cloud cover amount and SMP, and the lowest correlation coefficient was (R= -0.36 ± 0.34) for the high cloud cover amount with SMP. Therefore, we can assume that the solar activity has an impact on the cloud cover amount over Baghdad city.

Keywords: Solar activity, cloud cover.

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الخلاصة

ان الغطاء الغيمي عامل مهم في السيطرة على الطريقة التي يتم بها امتصاص وانعكاس الاشعاع من قبل الارض. ان الزيادة في كمية الغيوم تؤدي الى زيادة البياض العالمي، وهذا يؤدي الى تبريد سطح الارض والتأثير على الخصائص الاشعاعية والتأثير على المناخ بشكل عام، وبالتالي يؤدي الى الاحترار العالمي والتغيرات المناخية.

ان هذا البحث هو محاولة للدراسة وفهم تأثير الفعالية الشمسية على كمية الغطاء الغيمي فوق مدينة بغداد للفترة (1983-2009) من خلال تحليل بيانات القيم الشهرية لكمية الغطاء الغيمي عند المستويات (الواطئة، المتوسطة والعالية) و كمية الغيوم الكلية ، كذلك تحليل القيم الشهرية للاشعة الكونية المجرية GCR و (SMP) Solar Modulation Potential للفترة (1983-2009)، وتم استخدام package climate data operators لاجراء تحليل البيانات.

ان الهدف الاول لهذه الدراسة هو تحديد معامل الفعالية الشمسية (SMP) Solar Modulation Potential بدلا من الاشعة الكونية المجرية GCR وتم اختيار SMP كمؤشر للفعالية مع معامل ارتباط وقدره (0.8) مع GCR . وكان الهدف الثاني من هذه الدراسة هو التحقق من وجود علاقة بين بين SMP كمؤشر للنشاط الشمسي مع الغطاء الغيمي فوق مدينة بغداد للفترة (1983-2009). اظهرت النتا~ج في هذا البحث الى وجود علاقة بين مؤشر الفعالية الشمسية SMP وكمية الغيوم وكانت اعلى قيمة لمعامل الارتباط هي (R=-0.71±0.22) بين كمية الغيوم الكلية و SMP بينما كانت ادنى قيمة لمعامل الارتباط وهي (R=-0.36±0.34) بين كمية الغيوم العالية و SMP . لذلك يمكننا ان نفترض ان للنشاط الشمسي تأثير على كمية الغيوم فوق مدينة بغداد.

1. Historical perspective and Introduction

Solar variability has long been suspected as having a significant influence on climate change. Solar cycles of magnetic variability result in changes in the luminal spectra of the sun, the properties of the solar wind, and the flux of galactic cosmic ray's incident on earth's atmosphere. Changes in the total solar irradiance (TSI) with enhanced extreme ultraviolet (EUV) emission have been hypothesized to induce a dynamic air/ocean circulation response resulting from stratospheric ozone production (Lean & Rind 1998). The configuration of the interplanetary magnetic field (IMF) deflects and entrains galactic cosmic radiation (GCR) that transits the sphere of influence controlled by the sun, i.e., the heliosphere. During periods of heightened solar activity, fewer galactic cosmic rays (GCRs) are detected by earthbound neutron monitors. GCR flux and its correlation with cloud cover remain the most controversial of potential variables influencing the climate system (Krahenbuhl 2015). (Svensmark & Friis-Christensen 1997) suggested a modulation of the earth's total cloud cover by variations in the galactic cosmic ray (GCR) flux. This hypothesis was subsequently modified by (Marsh & Svensmark 2000), by linking the GCR flux to low clouds, which have a particular strong cooling effect on climate. (Kristjansson et al. 2004) asserted that the GCR flux has decreased throughout the 20th century, causing a decrease in low cloud cover by more than 8% and a significant fraction of the observed global warming and asserted that the correlation between low cloud cover and solar irradiance (positive feedback) is better than between low cloud cover and sunspot number. (Svensmark 2000) confirmed that solar activity is causing the annual temperature variations on earth by demonstrating the correlation between the cosmic ray flux and the variations in earth's cloud cover. Svensmark claimed if the influence of cosmic rays on clouds is real, then the ionisation produced by GCR affects the micro- physics in cloud formation. (Carslaw et al. 2002) provided further explanation on the influence of cosmic rays on cloud formation, and suggest further laboratory studies at the mechanistic level to understand these ion–aerosol–cloud interactions. In addition, there is no clear relationship between cosmic rays and clouds since the low cloud– cosmic ray correlation is affected by higher clouds in some geographical regions where low clouds may also affect the relationship between higher clouds and cosmic rays in some regions (Usoskin et al. 2006). (Pierce & Adams 2009) reached a similar conclusion about the ion–aerosol clear–air mechanism, suggesting that it is too weak to explain the putative correlations between cloud cover and the solar cycle. (Laut 2003) has brought into question the validity of the results regarding the relationship of lower- troposphere global cloud cover to the intensity of GCRs. Laut suggests that low-cloud data, based exclusively on satellite IR data, may be adversely affected by the presence of high clouds. (Palle 2005) has also questioned the validity of using the satellite-observed low-level cloud cover, showing the adverse effects of overlying cloud layers. (Krissansen-Totton & Davies 2013) found "no statistically significant correlations between cosmic rays and global albedo or globally averaged cloud height, and no evidence for any regional or lagged correlations". (Usoskin & Kovaltsov 2008) find strong statistically significant correlations between low clouds and GCR flux in limited geographical regions: the Atlantic Ocean and Europe. (Voiculescu & Usoskin 2012) stressed the importance of examining the correlation between GCR flux and cloud cover, at the regional level, specifically at climate defining regions. However, other studies have indicated that synoptic scale changes in cloud cover are more likely correlated with regional climatological modes or oscillations rather than GCRs (Laken et al. 2012a).

2. Data and choose solar activity indicator

In this paper, we use the global monthly cloud cover data (%) for three levels low ($p > 642$ mb), mid-level (642–350 mb), high ($p < 350$ mb) and also total cloud cover in 1983−2009 as given by the International Satellite cloud Climatology Project (ISCCP-D2) dataset (http://isccp.giss.nasa.gov) in a $2.5^0 \times 2.5^0$ geographical grid. The monthly cloud cover data over Baghdad city, separated from global monthly cloud cover data at coordinates (33^0N 33^0 50’N, 44^0 E 44^0 80’E) for three levels (low, mid and high) and total cloud cover in 1983−2009 (figure 1) by the widely known package licmate data operators (CDO).

The monthly values of galactic cosmic rays (GCR) in 1983-2009 recorded by ground-based neutron monitors (NMs) is situated in Northern Finland from Oulu neutron monitor dataset used in this paper. And also used monthly sun spot numbers (SST) data in 1983-2009 as given by National Centers for Environmental Information (https://www.ngdc.noaa.gov).

This paper uses monthly values of the Solar Modulation Potential (SMP) in 1983−2008 during the solar cycle 22 −23 as given by (Usoskin et al. 2011). SMP is the solar activity index of GCR. However, the SMP is considered a more credible indicator of solar activity, because, like the GCR it originates outside of the Earth’s sphere.

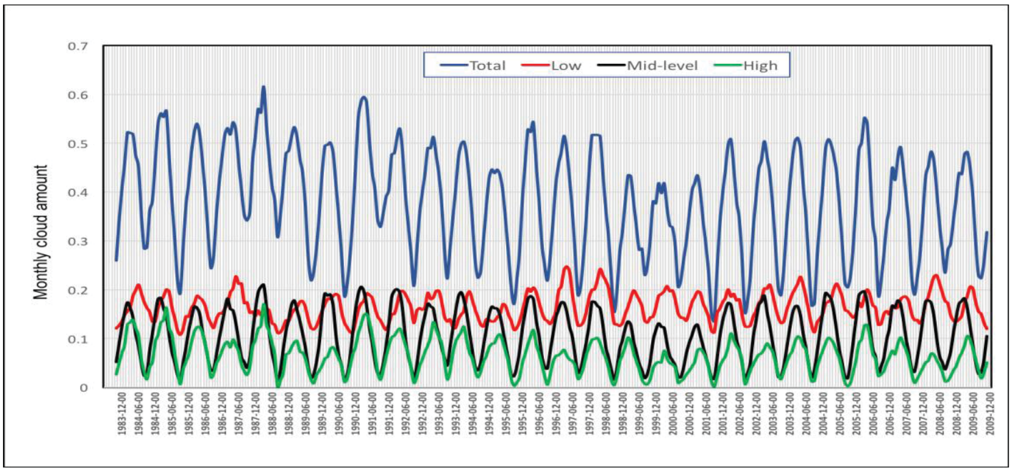

Fig. 1: The monthly cloud cover data over Baghdad in 1983-2009 low (red), mid-level (black), high (green) and total cloud cover (blue).

Figure 2a shows relation between the sun spot number (SSN) and the GCR in 1983−2009 and Figure 2b shows relation between SMP and GCR in 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, it is not identical completely, the SMP parameter is used here because it has a clear physical explanation and can be used by numerical models as an input parameter.

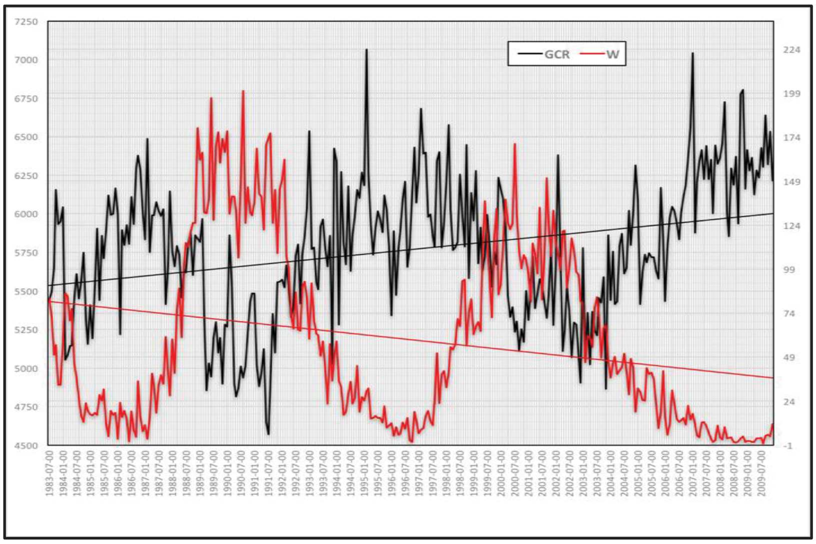

Fig. 2a: relation between the sun spot number (SSN) and the GCR in 1983−2009.

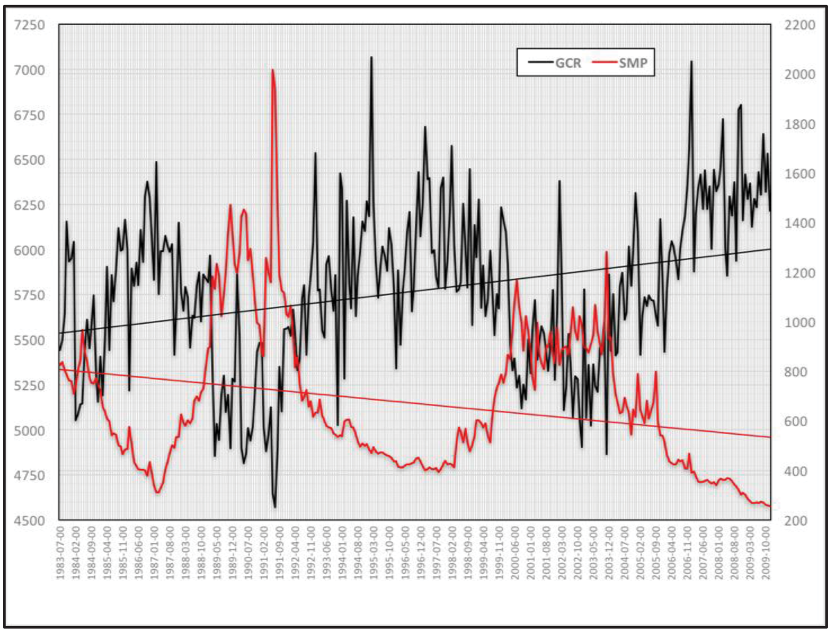

Fig. 2b: relation between the GCR and the SMP in 1983−2009.

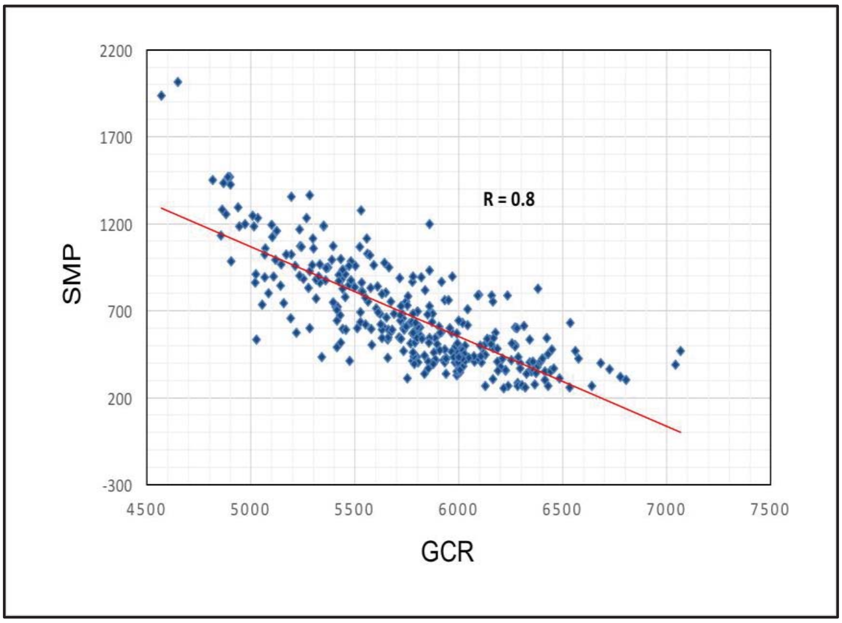

Fig. 3: Correlation between GCR and SMP in 1983-2009

3. GCR-cloud mechanism

There are two proposed mechanisms are the ion-aerosol clear-sky mechanism and the ion-aerosol near-cloud mechanism. The ion-aerosol clear-sky mechanism has got most of the mainstream attention, and the recent CLOUD results test a portion of this mechanism.

3.1 Ion-aerosol clear-air mechanism

The central theme of the clear-sky mechanism (Fig. 4) is that cosmic rays affect ion concentrations in the atmosphere. Aerosol nucleation (the formation of ~1 nm particles in the atmosphere) is generally enhanced by the presence of ions. The particles formed through nucleation may grow through condensation of sulfuric acid and organic vapors to sizes where they can act as cloud condensation Nuclei (CCN) (the particles on which cloud drops form). If CCN are exposed to relative humidities above 100%, cloud droplets will form on them. Thus, a change in cosmic rays could potentially affect the number of cloud drops, which in turn may affect the amount of sunlight reflected by a cloud, the formation of precipitation and the cloud lifetime. The clear-sky mechanism is driven by 5-20% changes in ion formation rates in the troposphere (Pierce & Adams 2009).

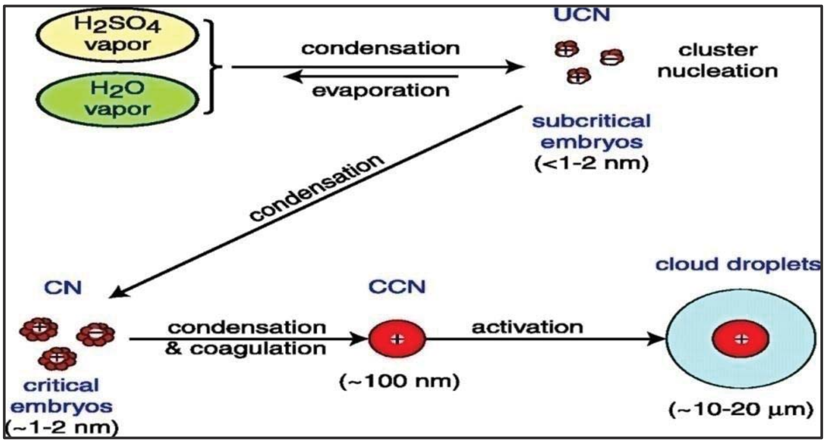

Fig. 4: An "ion-aerosol clear-air" mechanism proposed to link variations in cosmic ray intensity with cloudiness. The diagram shows the ion- catalyzed nucleation of new ultrafine condensation nuclei (UCN) from trace condensable vapors in the atmosphere, which may then grow into new cloud condensation nuclei (CCN) (Carslaw et al. 2002).

3.2 Ion-aerosol near-cloud mechanism

In the near-cloud mechanism (Fig. 5), the distribution of charge on aerosols near clouds is suspected to be modulated by the cosmic-ray flux. Aerosol charging affects the collection rate of unactivated aerosols by cloud droplets. The change in collection could affect the freezing of super cooled droplets by contact freezing (during aerosol scavenging). The direction and magnitude of the effect of cosmic rays on clouds in the near-cloud mechanism is currently very uncertain (Snow-Kropla et al. 2011).

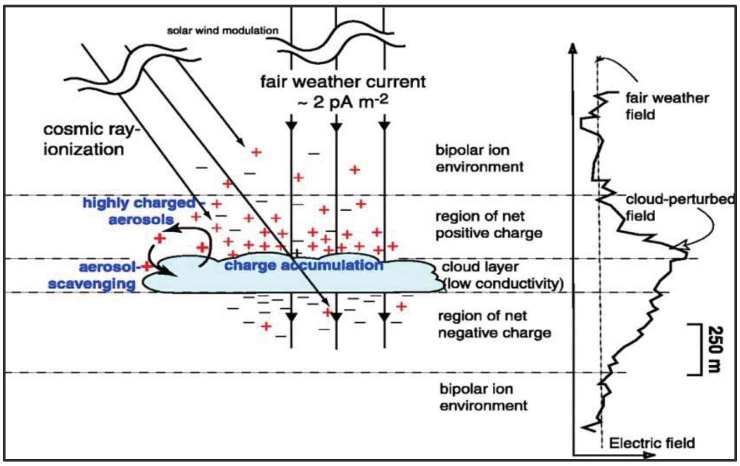

Fig.5: An "ion-aerosol near cloud" mechanism. The diagram shows the development of highly charged aerosols at cloud boundaries, which may then migrate within clouds and possibly enhance the formation of ice particles. The vertical scale is also shown (Carslaw et al. 2002).

4. Results and discussion

4.1 SMP – (Low, Mid-level and High) cloud cover correlations

Figures 6,7and 8 show the yearly variations of (low, Mid-level and high) cloud cover amount with SMP over Baghdad city during the period of the study, respectively. In these figures, we observe that the variation of cloud cover amount follows the variation of SMP, and the changes of the cloud cover is a clearly response to changes in SMP. These figures also show a decrease in the SMP (increase in the GCR) value with a consequent increase in cloud cover amount. This case is interpreted through the increase in solar activity, which results an increase in the availability of the amount of GCR particle flux, as well as the availability of the amount of cloud condensation Nuclei (CCN) in the lower troposphere. It is also possible to note in fig. 6 and 7 that the trend of low and mid-level cloud cover over Baghdad is increasing in response to the decrease in the trend of the solar activity index (SMP) for the solar cycles (23-24), This supports that the response to changes in the amount of low and mid-level cloud cover is affected by changes in GCR on the long-time scale. But in fig. 8 shows a different case for trend of high cloud cover over Baghdad, note its decrease, which not response to the decrease in the trend of solar activity index (SMP), In other words, the increasing in the GCR does not result in the response of the high cloud cover amount, and therefore does not support the response to changes in the amount of high cloud cover is affected by changes in GCR on the long-time scale. The increasing trend during the solar cycles (23-24) of the GCR values can be observed in Figure 2a and Figure 2b.

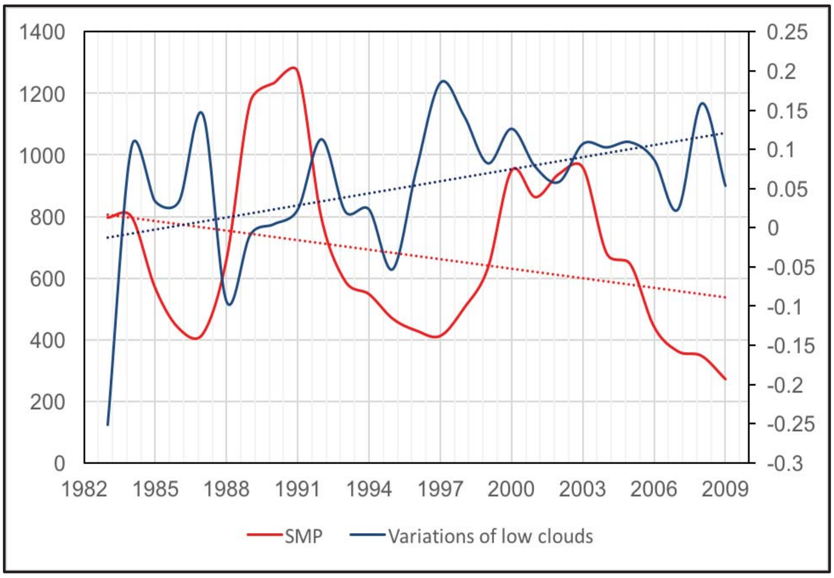

Fig. 6: Annual low cloud cover amount (%) and annual SMP over Baghdad in 1983−2009.

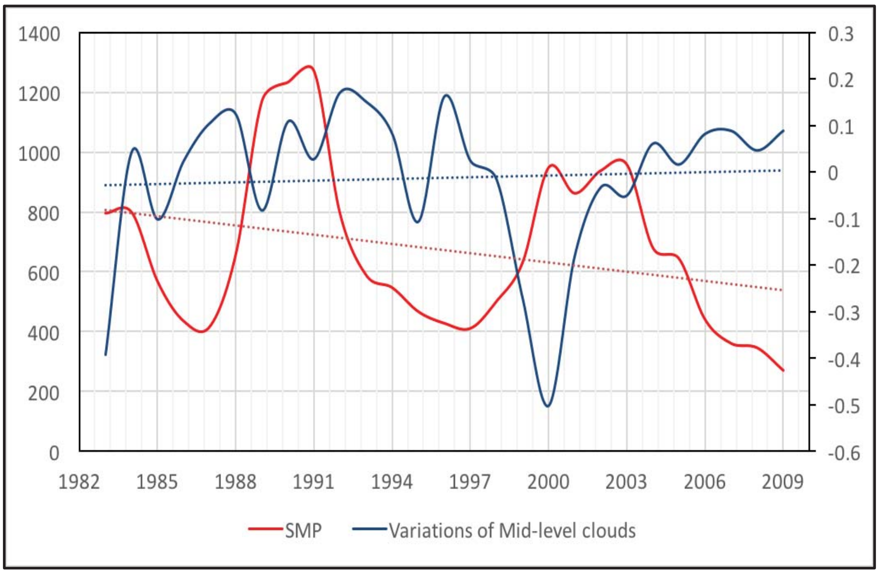

Fig. 7: Annual Mid-level cloud cover amount (%) and annual SMP over Baghdad in 1983−2009.

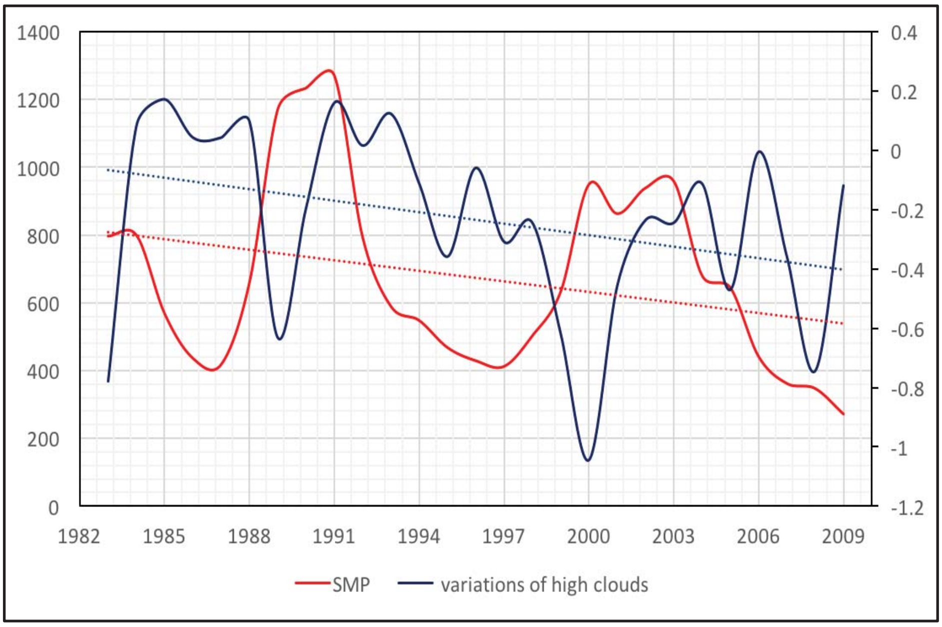

Fig. 8: Annual High cloud cover amount (%) and annual SMP over Baghdad in 1983−2009.

In Figures 9,10 and 11 shows the variations of cloud cover amount and the values (SMP), the relationship between them is inverse and has a correlation coefficient (R = -0.64 ± 0.18), (R= -0.43 ± 0.25) and (R= -0.36 ± 0.34) for low, mid-level and high cloud cover, respectively. (This value of the correlation coefficient between low cloud cover and SMP is good for the geographical location of the city of Baghdad, which is located within the mid-latitudes (latitude 33^0 N), which receives a small amount of GCR for the high latitudes where the GCR amount are very high. But the correlation coefficient between mid-level and high cloud cover and SMP is weak. That is means the Ion-aerosol clear-air mechanism supports only the results of low clouds in the lower troposphere. The positive correlation between solar activity and low cloud cover was noticed earlier over the United States (Udelhofen & Cess 2001), Ireland (Pallé & Butler 2001), North Atlantic, Europe and South Atlantic (Usoskin & Kovaltsov 2008), in the tropics and in mid-latitudes (Pallé & Butler 2001).

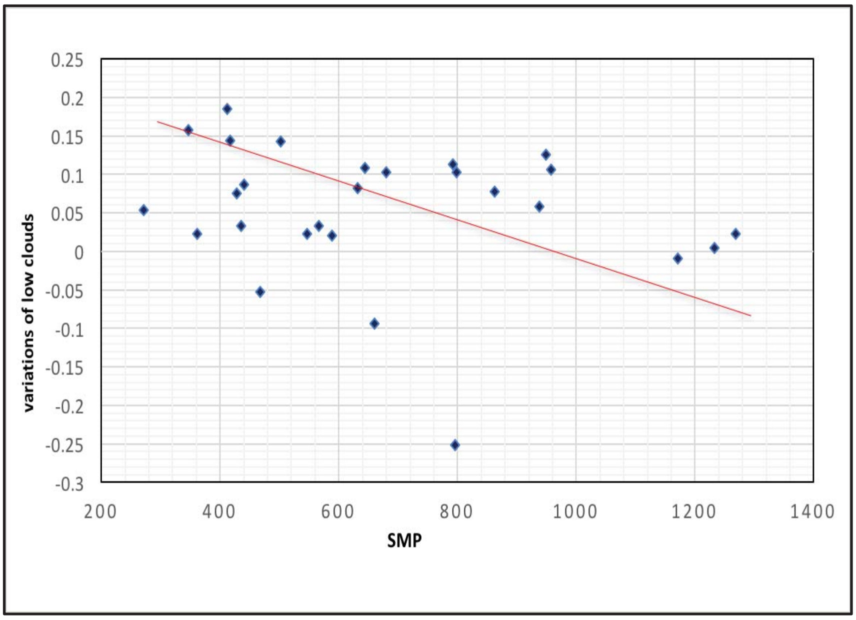

Fig. 9: Dependence of low cloud cover amount on SMP.

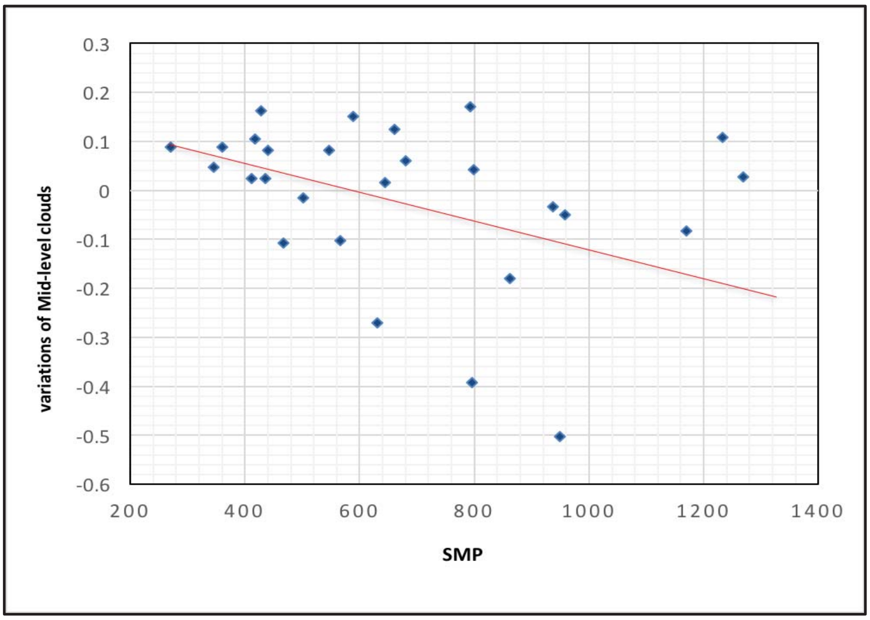

Fig. 10: Dependence of Mid-level cloud cover amount on SMP.

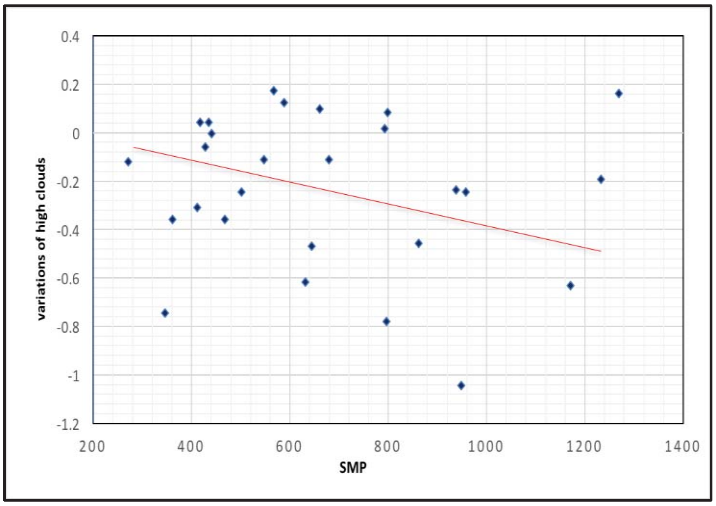

Fig. 11: Dependence of High cloud cover amount on SMP.

4.2 SMP - Total cloud cover correlations

Figure 12 shows the yearly variations of total cloud cover amount with SMP over Baghdad city during the period of the study, the total cloud cover exhibits very similar patterns to low cloud cover. The relation between the amount of total cloud cover with the SMP is also inverse as in other cloud types. this confirms the significant influence of solar activity on the cloud cover. this figure shows a clear response in the total cloud cover changes with the changes in the solar activity index (SMP), especially at the highest and lowest values in the SMP curve during 27 years. This response is higher than the other cloud cover types (low, mid-level and high). the influence on the long-time scale, is not responding, where the trend of total cloud cover over the Baghdad city tends to decrease with a decrease in the trend of SMP (increase in the GCR) as similar pattern of the high cloud cover during the solar cycles (23-24). The increasing trend during the solar cycles (23-24) of the GCR values can be observed in Figure 2a and Figure 2b.

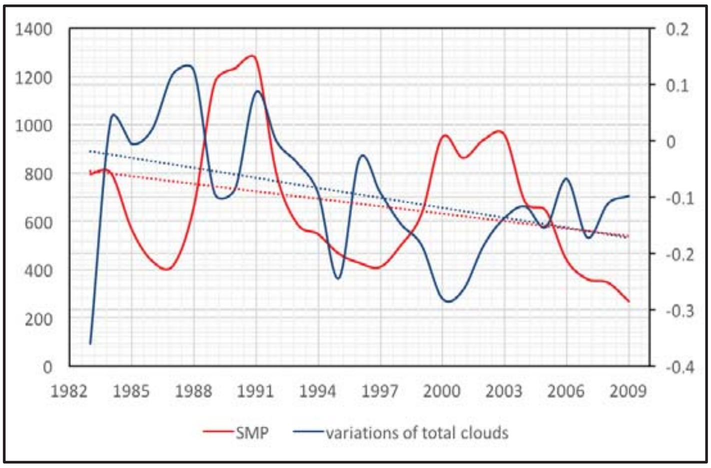

Fig. 12: Annual total cloud cover amount (%) and annual SMP over Baghdad in 1983–2009.

Figure 13 shows the variations of total cloud cover amount and SMP values. This inverse relationship has a correlation coefficient R = (-0.71 ± 0.22). This correlation is very good as well as higher than the other cloud cover types (low, mid-level and high).

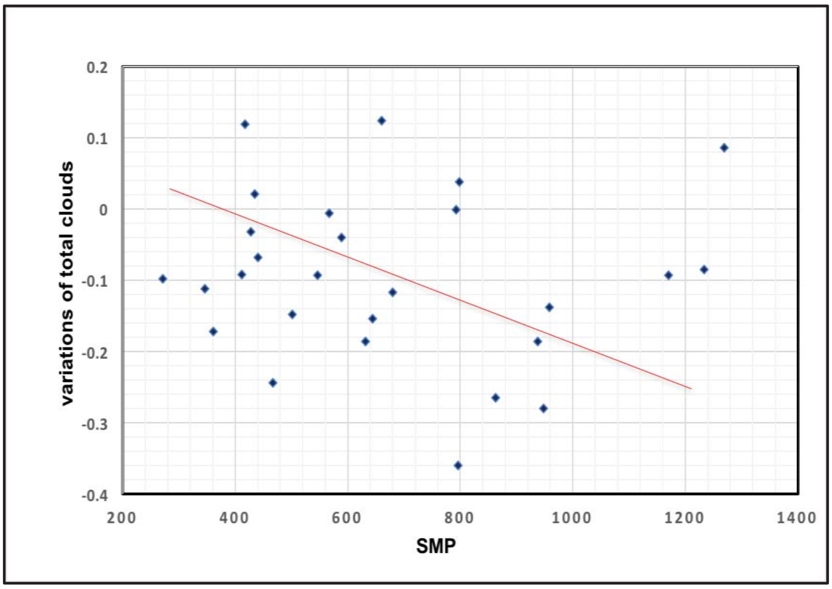

Fig. 13: Dependence of Total cloud cover amount on SMP.

5. Conclusion

The purpose of this study was to investigate the influence of solar activity on cloud cover over Baghdad city in 1983-2009 using the most updated data sources available. This was done mainly through an updated statistical analysis, but also by a consideration of some of the possible physical mechanisms. Broadly speaking, the analysis has confirmed a previous suggestion of a positive correlation between cloud cover and Solar activity variation. However, we find this correlation between solar activity index (SMP) and (low and total cloud cover) to be statistically significant with correlation coefficients (R = -0.64 ± 0.18) and (R = -0.71 ± 0.22) for low and total cloud cover, respectively. The correlation between (mid-level and high cloud cover) and solar activity index (SMP) is much weaker than that for solar activity index (SMP) and (low and total cloud cover) with correlation coefficients (R= -0.43 ± 0.25) and (R= -0.36 ± 0.34) for mid-level and high cloud cover, respectively, although these correlations is weak but it's important in terms of impact on the albedo and the climate in general. we find the trend of low and mid-level cloud cover over Baghdad is increasing in response to the decrease in the trend of the solar activity index (SMP) for the solar cycles (23-24), This supports that the response to changes in the amount of low and mid-level cloud cover is affected by changes in GCR on the long-time scale. but for the trend of high and total cloud cover not response to the changes in the trend of solar activity index (SMP) on the long-time scale.

Therefore, we can assume that the solar activity has an impact on the cloud cover amount over Baghdad city.

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