POSSIBILITY OF A PHYSICAL CONNECTION BETWEEN SOLAR VARIABILITY AND GLOBAL TEMPERATURE CHANGE THROUGHOUT THE PERIOD 1970-2008

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ABSTRACT
The present work introduces a correlative study to investigate the possible effect of some geomagnetic and solar parameters on global surface temperature anomalies (*GST*). Monthly averages of *GST* anomalies through the period from 1970 till 2008 and four solar-geomagnetic activity indices have been used. The indices are the geomagnetic activity (*aa*), the sunspot number (*Rz*), and the dynamic pressure (nv^2) throughout a period of 39 years (1970-2008) and total solar irradiance (*TSI*) throughout a period of 24 years (1979-2003). Scatter plots are used to show the association between *GST* and each of the solar-geomagnetic activity indices at zero lag. Running cross correlation analyses were applied between *GST* and each of these indices at different lags. Finally a series of power spectral densities (PSD) have been obtained. Our results reveal increase in *GST*-solar variability correlations indicated that 40-50% of this increase in *GST* is due to solar forcing. It is also found from correlation analysis that the change of nv^2 over GST carries a phase shift of about 47 months (~4 yrs), with the change of *Rz* and *TSI* while it experiences a phase shift of 35 months (3 yrs) with the change of *aa*. Similarities between sets of significant peaks in the spectra of *GST* and solar geomagnetic activities have revealed from power spectra analyses.

KEYWORDS: *Geomagnetic indices, Global surface temperature; Solar activity; Spectral Analysis; Sunspot numbers.*

1. INTRODUCTION

The Sun is the source of the energy that causes the motion of the compact atmosphere and thereby controls weather and climate. Any change in the energy from the Sun received at the Earth's surface will therefore affect climate. During stable conditions there has to be a balance between the energy received from the sun and the energy that the Earth radiates back into space. This energy is mainly radiated in the form of long wave radiation corresponding to the mean temperature of the Earth. Global surface temperature (*GST*) is a critical measure of climate variations. The debate concerning global warming has been the concern of researches for a long time.

Over the past century or so, the Earth's *GST* has increased by approximately 0.6°C±0.2°C. Temperatures in the lower troposphere have increased between 0.08°C and 0.22°C per decade [1 and 2]. Many theories discussed the impact of man-made causes and their effects on climate changes. The most common global warming theories attributed such increases to the greenhouse effect caused primarily by anthropogenic (human-generated) carbon dioxide (CO_2) and to elevated solar activity [3, 4 and 5]. Climate models, driven by estimates of increasing CO_2 and to a lesser extent by generally decreasing sulfate aerosols, predict that temperatures will increase (with a range of 1.4°C to 5.8°C for the years between 1990 and 2100). Climate commitment studies predicted that even if levels of greenhouse gases and solar activity were to remain constant, the global climate is committed to 0.5°C of warming over the next hundred years due to the lag in warming caused by the oceans. Hence, solar activity and green house gases play an important role in changing the climate.

Studies of El-Borie and Al-Thoyaib [6 and 7] displayed that the temperature should lag the geomagnetic activity index (*aa*) and the correlation reaches a maximum when temperature lags by 6 years. Since there is a linear relationship between *GST* and both *aa* and *Rz* (the sunspot number) the 185 % rise in the Sun's geomagnetic disturbances since 1901 corresponds to a rise in the *GST* by +0.32°C [2]; that increase of 0.32°C potentially accounts for nearly half of the change in the Earth's *GST* over the same period. In addition, the increase in *Rz* was 6.3/decade, on the average, since 1900 which reflected a rise of +0.03°C in the mean temperature. Previous works by El-Borie [8 & 9] displayed some indications that the increase in solar activity had meteorological effects within days after solar eruptions, which generate high speed solar wind streams (HSSWS). El-Borie *et al.*, [10] present a correlative study of the possible contributions for the two components *aa* and *Rz* that may be closely associated with the climate, throughout the last 128 years (1880-2008).

Generally there are two classes of physical mechanisms employed to describe the fluctuations in *GST*. The first involves strong correlations between total solar irradiance (*TSI*) and low cloud cover [[4]]. The average increase in *TSI* is about 3 W/m^2 from a base line of 1,365 W/m^2 from satellite heights during the peaks of solar cycles compared to the troughs. However, amplifying mechanisms for *TSI* are required to account for the moderately good correlations found between *TSI* and climate [[11]]. The second involves the dynamic pressure (nv^2) due to increased velocity or density of the solar wind (IMF) that can result in the production of energy within the Earth's magnetic field and can affect the troposphere. [[12]] found a small increase in dynamic pressure (in the order of nPa) from the solar wind due to expansion of solar magnetic corona; this may be sufficient to produce the energy that has resulted in increasing the surface temperature of the Earth.
The aim of this work is to study the possible role of some solar variability parameters such as the geomagnetic activity, *aa*, the sunspot number, *Rz*, and the dynamic pressure, nv^2, through a period of 39 years, (468 months from 1970 to 2008), as well as the total solar irradiance, *TSI*, through a period of 24 years (288 months from 1979-2003) in global temperature changes.

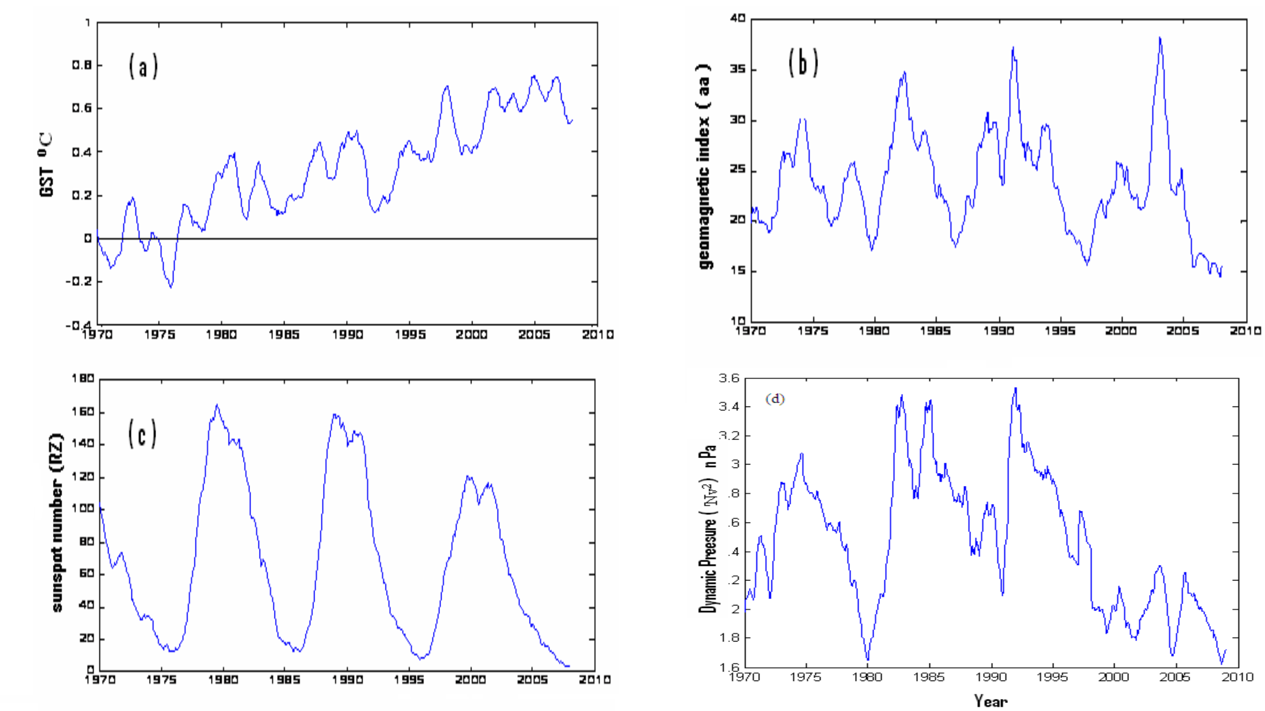
2. DATA AND ANALYSIS

The monthly averages of *GST*, *aa*, *Rz* and nv^2 for the period 1970-2008, and *TSI* for the period 1979-2003 have been used in this work. Data for the *GST* are available at (http://data.giss.nasa.gov/gistemp/tabledata/glb.ts.txt). In addition, data for *aa* index[1] and *Rz* were provided by the National Geophysics and Solar Terrestrial Data Center (http://www.ngdc.noaa.gov/stp/GEOMAG/*aa*star.shtml). Data of ion density, *n* (kg/m^3), solar wind speed, *v* (m/s) and *TSI* were obtained from (http://www.ukssdc.ac.uk) and (http://omniweb.gsfc.nasa.gov/form/). Dynamic pressures (nv^2) were calculated as the product of ion density, *n*, and the square of solar wind speed, *v*. Scatter plots are introduced to show associations between *aa*, *Rz*, *TSI* and nv^2 with *GST*. Running cross-correlation analyses were applied between *GST* and each of the solar-geomagnetic activity indices, at different lags. Finally, a series of power spectral densities (PSD) have been obtained. The results of PSDs were smoothed using the Hanning window function in order to avoid spurious strengths often associated with peaks near the start and end of the data set.

3. RESULTS AND DISCUSSION

Time series of 12 months running average of *GST*, *aa, Rz*, nv^2 and *TSI* are shown in fig.1. Fig.1a indicates an increasing trend of GST of ~+0.2 ^{0}C/decade, reaching a minimum value of -0.19 ^{0}C in 1979 and a maximum value of +0.7 ^{0}C in 1998. It is obvious from Fig.1b that the *aa* maxima have an irregular pattern with two *aa* maxima (double peaked modulations), one near the maximum solar activity period and the other in the descending phase [[13]; [14]; [15]; & [16]]. It has believed that the first peak is caused by coronal mass ejections, whereas the second peak is caused by geomagnetic disturbances due to the coronal-hole fast streams, which are more frequent in this part of each solar cycle [[17]]. It is also observed that peaks have an increasing trend reaching their maximum values of ~38 nT in 2003, while in fig.1c, *Rz* shows cyclic variations with a period of 11 years and show a decreasing trend in peak values. nv^2 series (fig.1.d) drops to a value of 1.6 nPa in 1980 as it reaches its maximum value in 1992 in contrast with TSI having its maximum in 1980 (Fig.1e).

[1] is a measure of disturbances level of Earth's magnetic field based on magnetometer observations at two, nearly antipodal, stations in Australia and England



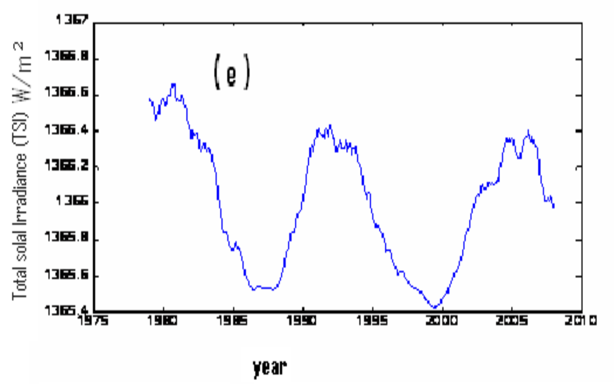


Figure 1 *(a-e) Monthly variations of GST, aa, Rz, nv^2, and TSI with time (1970-2008)*

From the scatter plot analysis of the 12-month running means (fig.2a), a coefficient of correlation of -0.319 was obtained between *GST* and nv^2; whereas a weak correlation of 0.09 was found between *GST* and *aa* at zero lag. Meanwhile, correlation coefficients of 0.47 and 0.36, relating *GST* with each of *TSI* and *Rz*, were calculating respectively at zero lag (fig.2b). Obviously, the strongest coefficient of correlation was observed between *TSI* and *GST*.

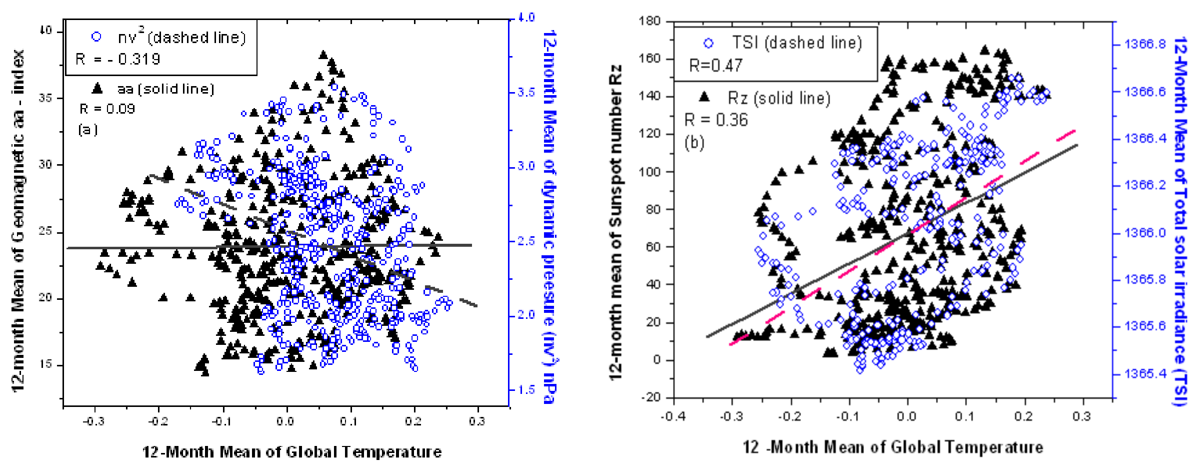


Figure 2 *(a & b) Scatter plots of monthly averages of GST with geomagnetic index aa and the product nv^2 (plot a) and Rz and TSI (plot b). Best-fit line and the correlation coefficients, r, are displayed.*

It would be interesting to re-analyze the correlations of solar parameters with *GST* at different lags. Running cross-correlation technique, with lag time of 120 months, was performed between each of these parameters and *GST* as shown in Figure 3.

Figure 3 presents correlations between *GST* and each of *aa*, nv^2, *Rz* and *TSI*. It clarifies no association between *aa* and *GST* at zero lag (confirming results obtained from the scatter plot analysis, fig.2a). The highest correlation coefficient of 0.5 is found between *TSI* and *GST* at a lag of -7 months whereas r = ~0.4 between *Rz*, *aa* and nv^2 with *GST* at lags of -7, -19 and -54 months, respectively. One can conclude that the GST-Solar variability indicated that 40-50% of the 0.7^0C increases in *GST* in the period 1970-2008 are due to solar forcing.

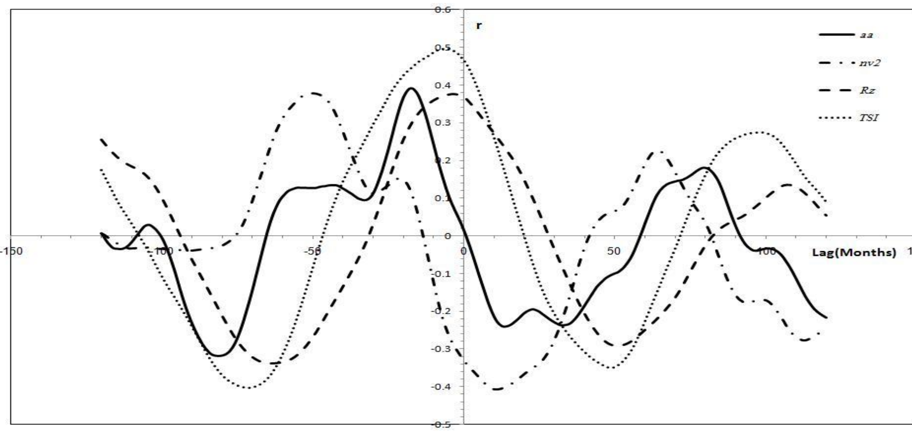


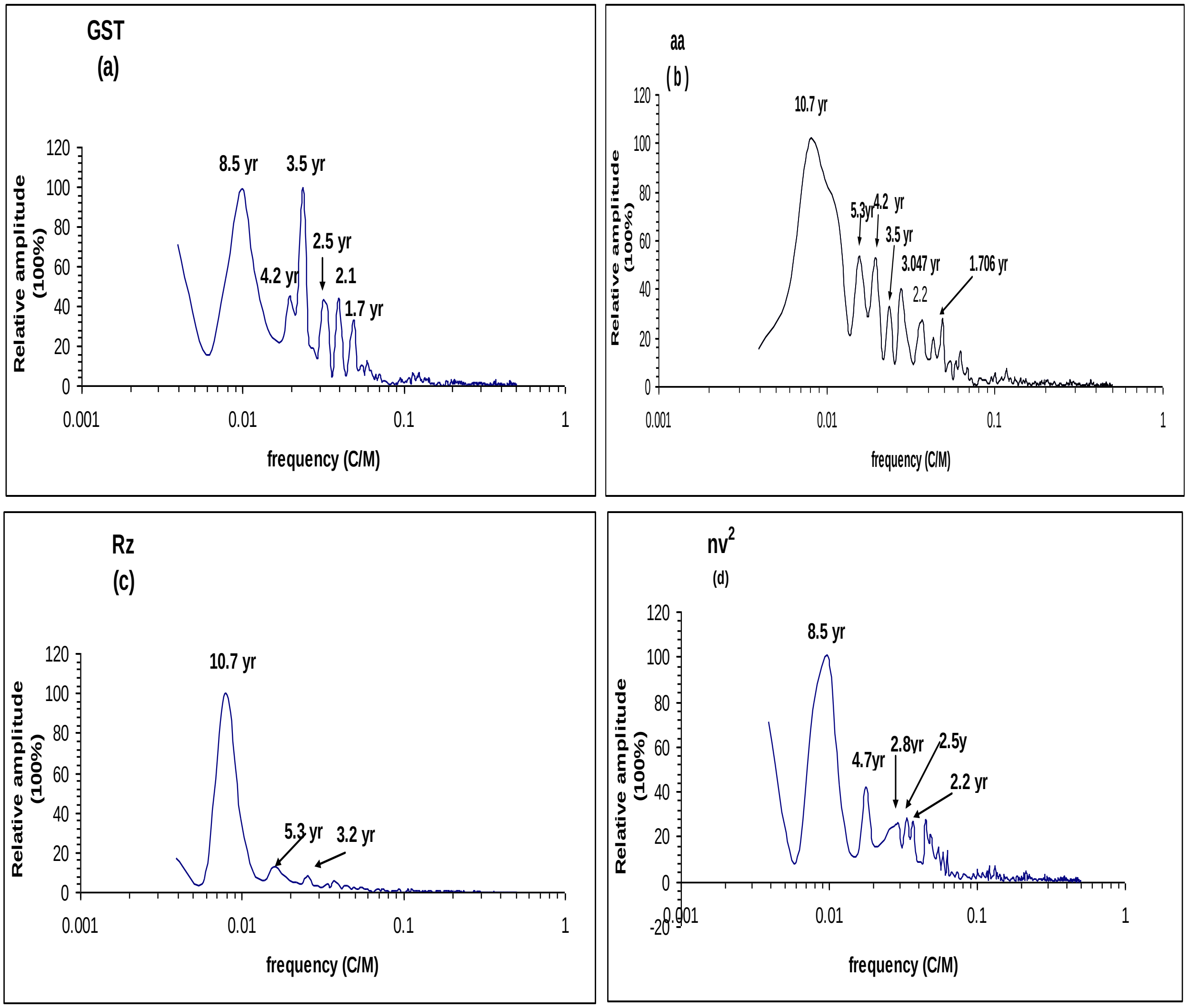
Figure 3 *Running cross–correlation (based on the monthly averages) between the GST with aa index and* nv^2 *(plot a, up) and Rz and TSI (plot b, down) with 120-month delay.*

Such a progress in the lag-time domain suggests that the change of nv^2 over *GST* carries a phase difference of about 140^0 or 47 months (~4 yrs) in phase angle or time space, respectively, with the change of *Rz* and *TSI*; while it experiences a phase shift of 105^0 or 35 months (3 yrs) with the change of *aa*.

A series of power spectral density (PSD) have been performed for the monthly average series (1970-2008). The results were smoothed using the Hanning window function and each spectrum is independently normalized to the largest peak in the complete spectrum. This restriction was chosen in order to avoid spurious strengths often associated with peaks near the start and end of the data set and in turn, there is no error into our identification of the peaks because it changes only the relative amplitude and not the position of the peak spectrum. The power spectral density is calculated for the wide range of frequencies (3.9×10^{-3} – 0.5 c/m), which corresponding to a range from 2 to 255 months (~ 21 yrs).

Figure 4 (plots a-e) shows a comparison of spectral characteristics between the PSD for the *GST*, *aa*, *Rz*, nv^2, and *TSI*. Numbers are added to assist in determining the relative locations of peaks in years (yrs). Plots show that there are no significant peaks observed in the high-frequency region corresponding to the period from ~ 2-15 m. A flat spectrum for the short-term fluctuations is observed. At the selected frequencies (> 1.5 yr) the spectral density is high and it shows significant variations frequency.

Significant peaks are observed (plot 4a) for *GST* at 8.5, 4.2, 3.5, 2.5, 2.1, and 1.7 yr, while plot 5b of *aa* displayed peaks at wavelengths 10.7, 5.3, 4.2, 3.5, 3.04, 2.2, and 1.7 yr. Furthermore, the PSD of the dynamic pressures of solar wind (plot 5d) showed significant peaks at 8.5, 4.2-4.7, 2.2-2.5 and 1.7 yr. Thus, the two solar parameters *aa* and nv^2, as well as the *GST* showed similar or common periodicities. Thus, the spectrum of solar couple (*aa* and nv^2) reflected nearly the same periodicities in the spectrum of *GST*. In plot 5c, in *Rz* spectrum a remarkable peak is observed at 10.7 yr, which was found in *aa* spectrum. In addition the *Rz* spectra displayed a small peak at 5.3 years. In contrast, the *TSI* series showed peaks in long period 10.7 year and small peaks at 6.1 and 4.2 yr.



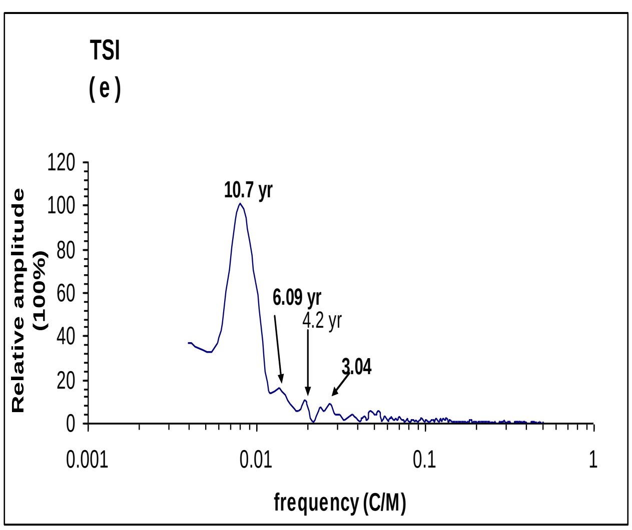


Figure 4 *(a-e) The power spectrum density (based on the monthly averages) for GST, aa, Rz,* nv^2*, and TSI. The PSD of each parameter is normalized to the maximum peak.*

The plots confirmed similar (or identical) fluctuations of 4.2, 3.5, 2.2-2.5, and 1.7 yr between *aa* and *GST*. Also, we found similar peaks 8.5, 4.2-4.7, 2.5, 2.2, and 1.7 yr between nv^2 and *GST*. The 5.3 yr variation found in *aa* and *Rz* may be attributed to the different paths of the ion particles in helioshpere. Similar periodicities of 5-5.2 years in the solar wind speed and ion spectral density were found [18, 19, & 20]. The 4.3 years, which is caused by the dual-peak structure of the geomagnetic activity or it is caused by sector boundary of crossings [21]. A simple explanation for 8.5 year peak is that it may be related to the formation rate and the magnetic structure of achieve regions in the solar southern hemisphere [22]. Finally we can say that the *GST* are strongly sensitive to the 8.5 yr, 4.2-4.7 yr, 3.5 yr, 2.2-2.5 yr, and 1.7 yr variations that observed in the considered geomagnetic and solar parameters spectra. Furthermore, the results of PSDs have displayed that the leading spectra of *aa*, *Rz* and *TSI* spectra precedes the leading peak of *GST* spectra, by a few years (2.2 years).

4. CONCLUSION

An increase in *GST* anomalies of ~0.7 ^{0}C in the last four decades has been revealed. From scatter plot analyses, a 32% anti correlation was found between nv^2 and *GST*; whereas no correlation was found between *GST* and *aa* at zero lag. *TSI* has the largest contribution in changes of *GST*. From running cross correlation analyses, it was found that the change of nv^2 over *GST* carries a phase difference of about 140^0 or 47 months (~4 yrs) in phase angle or time space, respectively with the change of *Rz* and *TSI*; while it experiences a phase shift of 105^0 or 35 months (3 yrs) with the change of *aa;* also, the *GST*-solar variability correlations indicated that 40-50% of the 0.7 ^{0}C increase in *GST* in the recent 39 years,1970-2008, are due to solar forcing. We think that the solar and anthropogenic greenhouse forcing are roughly equal contributors to the rise in *GST* during the recent years. Similarities between the sets of significant peaks (8.5, 4.2 and 3.5 yrs) in the spectra of *GST* and solar geomagnetic activities in the period (3-10 years) have revealed from power spectra analyses.

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