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Effect of Solar Activity on Earth's Climate during Solar Cycles 23 and 24

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Abstract

The Sun's energy that drives the weather system might connect the Earth's climate changes for the period 1996-2016. The Sun's activity could explain the global warming in the 21st century. The Sun-Earth connection has to influence thermosphere, atmosphere, and ionosphere. The effects of the solar variability are evident in a variety of physical and chemical process in the upper atmosphere. In the present study, we have found a global surface temperature anomalies change (a factor ~1.29 °C) from 1996 to 2016. We have found a positive correlation between total solar irradiance (TSI) with Kp-Index, AE- Index and global surface Temperature anomalies (GTA) during solar cycles 23-24. We have found that the effect of these parameters in the Earth's climate is very minimal.

Keywords – Solar activity (TSI, AE, Kp), Global surface temperature anomalies (GTA),

Introduction

A full understanding of the influence of solar variability on the Earth's climate requires knowledge of the short-term and long-term solar variability, and solar-terrestrial interactions of the Earth's climate system (Rind, 2002). Total solar irradiance (TSI) is Earth's dominant energy input which provides energy that establishes Earth's climate. Small changes in this energy over long periods of time potentially affect Earth's climate, as demonstrated in modern times by Eddy (1976) and substantiated by more recent studies (Haigh, 2007; Lean and Rind, 2008; Ineson *et al.,* 2011; Ermolli *et al.,* 2013; Solanki *et al.,* 2013).TSI describes the total radiant energy, in the form of electromagnetic radiation emitted by the Sun at all wavelengths, that falls for each second on 1 square meter outside the Earth's atmosphere, a value proportional to the "solar constant" introduced earlier in the previous century (Haigh, 2007).

The spatially and spectrally integrated radiant energy from the Sun incident at the top of the Earth's atmosphere, which averages 1361 W m^{-2}, is now termed the total solar irradiance (TSI) and has been measured with space-borne instruments continuously since 1978. We will see evidence of solar irradiance influence on Earth surface and atmospheric temperature (Lean, 2010; Gray *et al.,* 2010).The average increase in solar radiative forcing since 1750 is much smaller (~ 0.12 W m^{-2}) than the increase in RF due to heat-trapping gases (~2.6 W m^{-2}) over that same time period. Although very little of the Sun's output is in the UV, the Sun's variability is much greater at these shorter wavelengths. This shortwave solar radiation is mostly absorbed in the Earth's middle and upper atmosphere. There have been suggestions that twentieth-century global and hemispheric mean surface temperature variations are correlated to longer-term solar variations. Even small variations in solar irradiance can produce natural forcing of Earth's climate with global and regional scale responses (Intergovernmental Panel on Climate Change (IPCC), 2007; Lean and Rind, 2009).

The K_p index, generally taken to be a measure of the strength of the solar-wind flux, may be more acceptably interpreted as a measure of the time rate of change of the sum of plasma plus magnetic pressure acting on the magnetosphere. The magnetic irregularities that have been observed outside the magnetosphere do not appear to be hydro-magnetic waves, but most likely are quasi-static irregularities that are swept past the detectors by the solar-wind flow. The Auroral Electro-jet Index (AE) shows a global, quantitative measure of the auroral zone in magnetic activity produced by enhanced Ionospheric currents flowing below and within the auroral oval. The Auroral Electro-jet Index (AE) is the interplanetary magnetic field and the behavior of communication satellites and radio propagation on the Earth's magnetosphere (Singh *et al.*, 2016).

Thus, although fluctuations in the amount of solar energy reaching our atmosphere do influence our climate, the global warming trend of the past six decades cannot be attributed to changes in the Sun (Hansen *et al.,* 2005) in figure 1.Carbon dioxide belongs to a category of gases known as heat-trapping gases or greenhouse gases. This "greenhouse effect" is nothing new: plants and animals have enjoyed the benefits of its warming influence for billions of years. Without the greenhouse effect, Earth's average temperature would fall below freezing. However, human activities are now increasing the concentration of carbon dioxide in our atmosphere, amplifying the natural warming caused by the greenhouse effect.

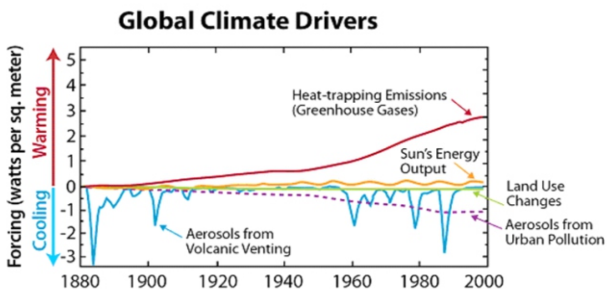

Fig. -1: Heat-trapping emissions (greenhouse gases) far outweigh the effect of other drivers acting on earth climate.

Global temperature is rising and GISS analysis of global surface temperature change first published in 1981 (Hansen *et al.,* 1981). The objective was an estimation of global temperature change that could be compared with expected global climate change in response to known or suspected climate forcing mechanisms such as atmospheric carbon dioxide, volcanic aerosols, and solar irradiance changes.

Data Detection and Method of Analysis:

We have taken monthly average total solar irradiance (TSI) in W/m^2 from TIM data files (http:lasp.colorado.edu/home/sorce/data/tsi-data). The Monthly mean global surface temperature anomalies (GTA) in ^{0}C from GISS (https://data.giss.nasa.gov) and a monthly average of Kp and AE (nT) from Omni web data (http://omniweb.gsfc.nasa.gov) for our selected period 1996 to 2016. In this study, we have observed the variation of TSI, GTA, AE, and Kp and also calculate the correlation coefficient between these parameters for the period 1996-2016.

Results and Discussion

Today, solar cycles and trends are recognized as important components of natural climate variability on decadal to centennial time scales. The attribution of present-day climate change, interpretation of changes prior to the industrial epoch, and forecast of future decadal climate change a natural variability, including by the Sun.

The main trigger mechanism of volcanic activity can be recurrent magnetic activity. Long-lasting, recurrent magnetic storms are produced by the joint action of the interplanetary magnetic field and solar wind velocity. Therefore, several years of global temperature drop can firstly be attributed to TSI variations, and then to volcanic signals that are also can be related to the geomagnetic activity. It is now generally accepted that centennial modulation of 11 years TSI driving alone is too small to explain global warming. TSI measurements differ widely in experiments and show the unusual behavior of ultraviolet irradiance during solar cycles.

Past study shows, temperature anomaly 0.4^{0}C for the period 1960 to 1980 (Hansen *et al.*, 1981) and an average temperature anomaly 0.16^{0}C for the period 1980 to 2000 (Lean, 2010). Figure 2 shows the global surface temperature anomalies and TSI monthly variation for the period 1996 to 2016. It is clear that global temperature anomalies (GTA) are increasing by a factor ~1.29^{0}C which is higher than previous study period (Lean, 2010). On behalf of temperature anomalies in the solar cycle, 24 is greater than the solar cycle 23. The GTA is coinciding with each other in ascending and descending phase of the solar cycle 23-24 (1998, 2003, 2011, 2012, 2013, 2014, and 2015). It is clearly evident that GTA varies accordingly to TSI. The physical mechanism of the influence of TSI on GTA variations in the Earth's atmosphere is small variated. Thus, the existence of a solar cycle effect on the main part of climate variations is unequal energy input of TSI to the lower atmosphere of the Earth's. In the period (1998-2001) GTA is minimum but TSI is maximum as well as for the period (2007-2010) GTA is increased but TSI is linearly increased. We have observed that the GTA is not only depends on the TSI and we conclude that the Earth's temperature is increased for the period 1996-2016.

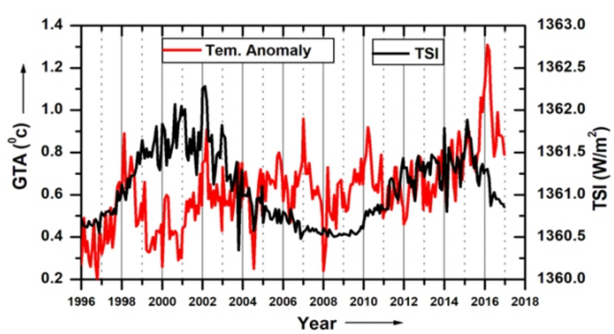

Fig.-2. The monthly variation of the global surface temperature anomalies (GTA) and TSI variations for the period 1996 to 2016.

Other indicators of solar activity have been observed over longer periods; these include TSI, AE, and Kp index, which gives a measure of the magnitude of the solar magnetic field at the Earth. Figure 3 shows that the monthly variation of TSI have aminimum value in 1996 and 2008 and get maximum value in 2002 and 2015. The TSI values vary from 1361± 0.790 in our study period 1996 to 2016. We have observed that variations of TSI with Kp and AE index coinciding with ascending phase of solar cycle 23 and 24 Kp and AE variations are maximum in the period 2003 as well as similar variations with TSI. The TSI gets its maximum value in 2002 and 2015. We have observed the higher TSI, greater Kp, and a higher incidence of lower-latitude AE (positive variations) occur when solar activity in ascending phase. Willson (1997) observed that TSI is 0.5 Wm^{-2} higher during the solar minimum of 1996 than during the solar minimum of 1986. In the duration of 1996-2016 are also affected by the Earth's climate by AE. It is observed that the AE and Kp is on the magnetosphere of the Earth's and we affected the Earth's climate.

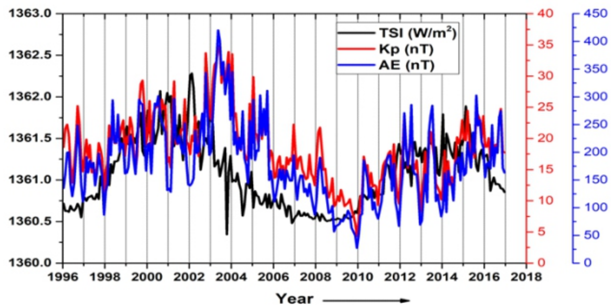

Fig. - 3. The monthly variation of TSI, AE, and Kp for the period 1996 to 2016.

From figure 4 (upper left and right panel) shows the scatter graph between Total solar irradiance (TSI) and AE index is positively correlated with solar cycle 23 and 24. We have found the correlation coefficient for solar cycles 23 is 0.32 as well as in cycle 24 is 0.42. From figure 4 (lower left and right panel) shows the scatter graphs between Total solar irradiance (TSI) and Kp-index is positively correlated in solar cycle 23 is 0.31 and for solar cycle 24 is 0.45. We have seen that solar cycle 24 is larger correlation coefficient as compared to the solar cycle 23.The scatter graph shows that TSI disturbed the earth magnetic field (AE, Kp) and it is positively correlated with each other. The correlation studies suggest that climate responds to solar activity but cannot give reliable quantitative estimates of the response because other factors may be contributing to the climate variability.

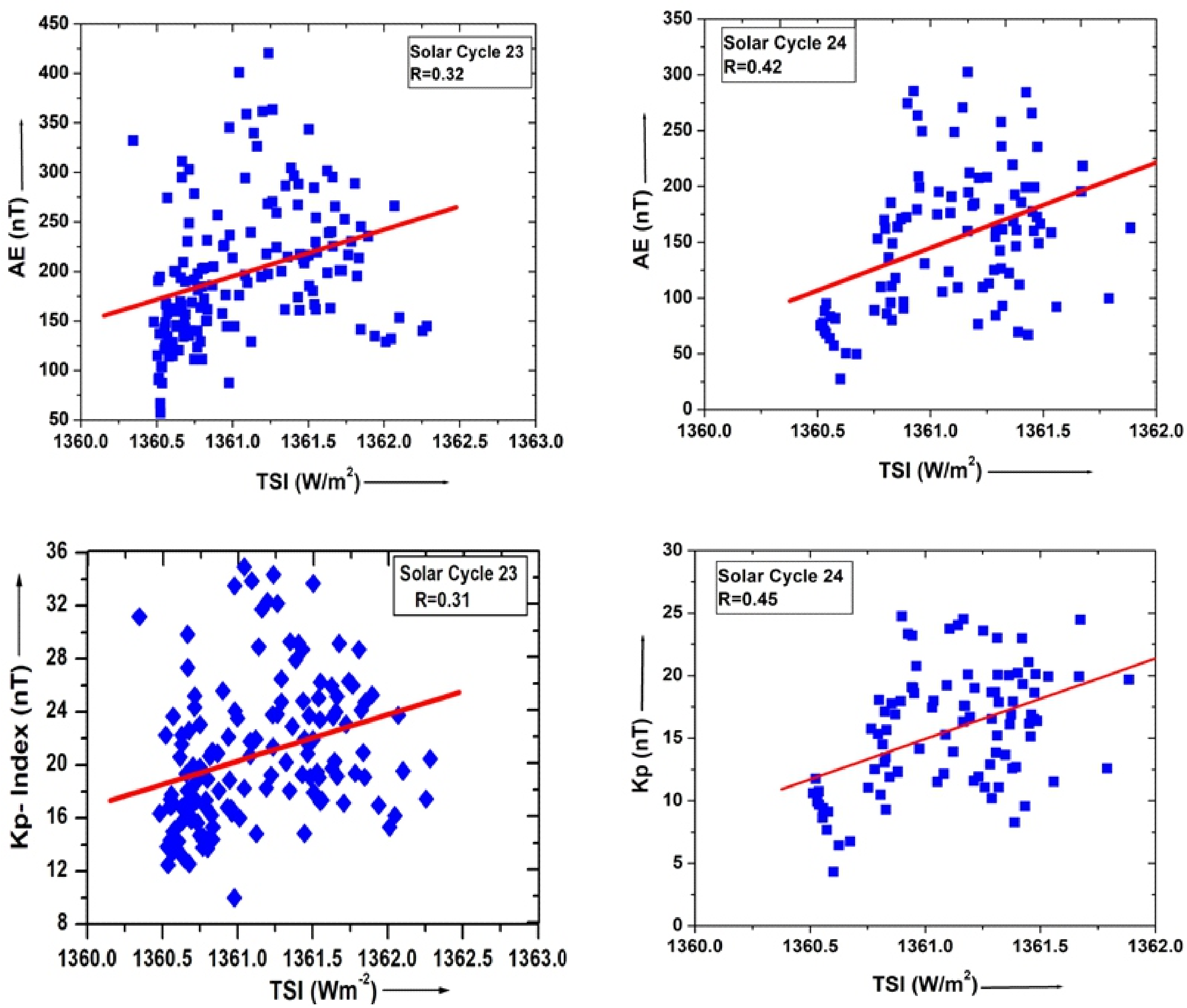

Fig. -4. Shows (upper left and right panel) Scatter graphs of Total solar irradiance (TSI) and AE- index, (Lower left and right panel) Scatter graphs of Total solar irradiance (TSI) and Kp- index for solar cycle 23 and 24.

The climate is found to be very sensitive to solar change and a significant fraction of global warming that occurred claims that the Sun has caused as much as 69% of recent global warming in last century should be solar induced (Scafetta and West, 2007).We have found the correlation coefficient between the TSI and GTA during solar cycles 23 is -0.13 and for solar cycles, 24 is 0.23. The scatter graph of total solar irradiance (TSI) and global temperature anomaly in solar cycle 23 and 24 (Figure 5) shows no good correlation exists between TSI and GTA in the study period 1996-2016 but it is significant in solar cycle 24.The low value of correlation does not mean that there is no effect of solar output in earth climate. Because of earth intercept (πR^2.TSI) solar energy per unit time whereas the surface area of earth spheres ($4\pi R^2$) i.e. one-fourth of total earth surface, the value of correlation shows significant value.

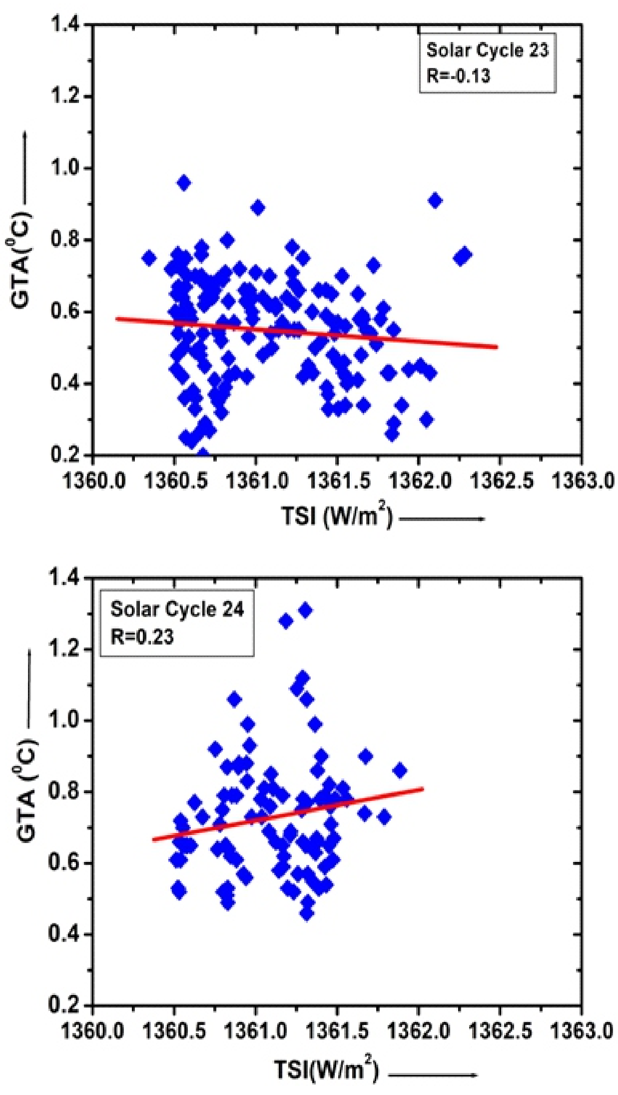

Fig. 5. Scatter graph of TSI and global temperature anomaly during the solar cycles 23 and 24.

Conclusion

The most probable value of total solar irradiance representative of solar energy is varied about~1.28Wm^{-2} for the period 1996-2016. It increased ~0.1% minima to maxima of two solar activity peaks 2001 and 2015.

TSI positively correlated with Kp and AE index i.e. it disturbed earth magnetic field. When TSI gets its highest value GTA also increase, i.e. GTA fluctuation being stronger when AE and Kp have a lower value.

No good correlation exist between TSI and GTA but it has a significant value i.e solar output affect the temperature (minimal) but the main cause of global temperature anomalies is due to greenhouse gas esemission on the Earth.

Finally, the role of solar variability in climate change has received much public attention because reliable estimates of solar influence are needed to limit uncertainty in the importance of human activity as a potential explanation for global warming.

For our calculations of TSI AE and Kp, trends do not show a significant effect, while the GTA trend is very large and significant.

The role of volcanic signals in the 11-year variations of the Earth's climate can express as several years of global temperature drop. This suggests that there are combined effects of solar, geophysical and human activity on climate change patterns.

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