International Journal of Physics and Mathematical Sciences ISSN: 2277-2111 (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jpms.htm
2015 Vol. 5 (1) January-March, pp. 35-41/Dubey and Pandey
Research Article

LONG-TERM VARIATION OF DIFFERENT SOLAR AND GEOMAGNETIC ACTIVITIES

[*]S.C. Dubey[1] and S.K. Pandey[2]
[1]Department of Physics, S.G.S. Govt. P.G. College, Sidhi (MP) Pin 486661, India
[2]Department of Physics, Rewa Engineering College, Rewa (MP) 486 002, India
**Author for Correspondence*

ABSTRACT
Long-term variations of different solar source activities and large geomagnetic disturbances also termed as geomagnetic storms (GMSs) which are associated with D_{st} decreases of more than 100 nT, and are observed during the period 1997-2011 have been analysed. It is found that 93 large GMSs falling in our selection criteria. We have established long-term variability of above selected 93 large GMSs with different solar source activities that provides a better aspect to understand the space-weather phenomenon. Long-term variation of sudden storm commencement (SSCs) for solar cycle 21-23 shows that annually occurred value of SSCs follows with sunspot number (SSN) during the period of solar cycle 22 and 23, but solar cycle 21 is exceptional among them. Long-term variation of Kleczek solar flare index (SFI) with annual mean SSN for the period 1976-2007 shows that the yearly occurred value of SFI varies with 11-year sunspot cycle. Long-term variation of solar radio flux (SRF) with annual mean SSN for the period 1976-2011, shows that the yearly occurred value of SRF varies with 11-year sunspot cycle as similar as variation of other solar transients. The long-term solar irradiance variations (TSI) have shown that the Sun has a slight cooling trend since 1976. Various space weather condition and climatic change have also been analysed.

Keywords: *GMSs, CMEs, SRF, SFI, SSCs, solar flares.*

INTRODUCTION
Terrestrial magnetosphere and upper atmosphere can be greatly perturbed by variations in the solar variations caused by disturbances on the Sun. The state of near-Earth space environment is governed by the Sun and is very dynamic on all spatial and temporal scales. Sunspots are huge magnetic storms that are seen as dark (cooler) areas on the Sun's surface. The number of sunspots peaks every 11 years. During periods of maximum sunspot activity, the Sun's magnetic field is strong. When sunspot activity is low, the Sun's magnetic field weakens. Solar plasma and magnetic field ejected out into interplanetary medium and produce extra ionization in the sunlit part of the earth and exhibits peculiar storm time changes in the observed geomagnetic field. Disturbances in the Earth's magnetic field can disrupt the operation of critical infrastructures relying on space-based assets but also can result in terrestrial effects, including disrupting electricity distribution networks. Solar variability is used to describe a number of different processes occurring mostly in the Sun's convection zone, surface (photosphere) and atmosphere. The influences of solar variability on the Earth's climate are determining the response of the Earth's climate system and their interactions. Conditions in the upper atmosphere vary greatly at different points on the globe with the change in the zenith angle of the Sun, just as with the regular weather on the surface of the Earth. There have been substantial increases in our knowledge of each of these areas in recent years and renewed interest because of the importance of understanding and characterising natural variability and its contribution to the observed climate change.
There are two types of geomagnetic field variations termed as long-time variation and storm-time variations. The long-term variations are very useful to solar cyclical study of geomagnetic field variation as well as change in polarity of the Sun, climate change, plants growth rate and geological change of Earth's pole. The storm time variations deal the various characteristics of GMSs and their connection with solar source activities and interplanetary magnetic fields. All GMSs produce terrestrial effects to some

degree but great GMSs have a direct effect to us and create many adverse effects within ionosphere and geomagnetosphere.

The Sun is the source of energy for the Earth's climate system. The Sun has a strong influence on climate. The 11-year solar cycle is the best known variability in the Sun. So, we have investigated association of geomagnetic activities and different solar source activities on long-term basis. Earlier studies show that large solar flares were responsible for interplanetary shocks and intense geomagnetic storms (GMSs). Joselyn and McIntosh (1981) have shown that the solar disappearing filaments have also been linked with large geomagnetic activities and interplanetary disturbances. Many recent studies and Skylab observations show that active sunspot regions, coronal mass ejections (CMEs), eruptive prominences and disappearing filaments are the active energy emitting regions and they produce large interplanetary and geomagnetic disturbances. The CMEs were discovered in coronagraph observations on the OSO-7 (Tousey, 1973). The CMEs play a key role in the solar-terrestrial relationship (Gosling, 1993). The correlations of CMEs and intense geomagnetic storms have been discussed for different periods by several authors (Dubey, 1998; Pandey and Dubey, 2009). CMEs that appear to surround the occulting disk of the observing coronagraphs in sky plane projection are known as halo CMEs (Howard et al., 1985). Halo CMEs are fast and wide on the average and are associated with flares of greater X-ray importance because only energetic CMEs expand rapidly to appear above the occulting disk early in the event. Gopalswamy et al (2007) have been detail discussed about single and multiple halo CMEs events and their different associations.

Kleczek (1962) first introduced the concept of the solar flare index (SFI). The solar flare index is a measure of this short-lived activity on the Sun. It represents total energy emitted by the flares. The amount of energy received from the Sun is measured daily in terms of the solar flux. The solar flux can vary from as low as 50 to as high as 300. During a sunspot maximum, solar flux values will typically exceed 200 resulting in excellent long distance HF communications on the 20 through 10-meter amateur bands. Solar flux values will range from 50 to 80 during sunspot minimums yielding poor long distance communications with 40 meters (7 MH_z) typically being the highest usable frequency band. Solar energetic particle (SEP) events occur when high-energy protons are ejected from the Sun's surface during fast solar eruptions and cause geomagnetic and ionospheric disturbances on large scale. These effects are similar to auroral events, the difference being that electrons and not protons are involved. These events typically occur at the North Pole, south pole, and South Atlantic magnetic anomaly, where the Earth's magnetic field is lowest. The more severe SEP events can cause widespread disruption to electrical grids and the propagation of electromagnetic signals. The long-term trends in solar irradiance appear more plausible and produced modeled climates in better agreement. Solar activity varies on shorter-time scales, including the 11-year sunspot cycle and longer-term as Milankovitch cycle. The cyclical nature of the Sun's energy output is not yet fully understood; it differs from the very slow change that is happening within the Sun as it ages and evolves

DATA ANALYSIS

The D_{st} index has been introduce by Sugiura (1964) and used for solar quiet daily variation. The data of D_{st} indices obtained from the WDC-2 Kyoto D_{st} index service. The data of the sunspot number (SSN), SEP events and solar flare index (SFI) were taken from the National Geophysical Data Center (NGDC). Solar radio flux from the entire solar disk at a frequency of 2800 MH_z (10.7 cm wavelength) has been recorded routinely by a radio telescope at the Algonquin Radio Observatory, near Ottawa since 14th February 1947. During the period (1997-2011), we have found 93 large GMSs that are associated with D_{st} decreases of more than 100 nT. Out of the selected 93 large GMSs, 54 are sudden commencement GMSs and rest 39 are gradual commencement GMSs. Yearly occurrence of sudden commencement, gradual commencement and total number large GMSs have no significant correlation between the maximum and minimum phases for solar cycle. It is also find that occurrence of large GMSs during its declining phase of solar cycle 23 is higher and shows controversial result measured at yet. During passed periods (2008-

2011) of solar cycle 24, only 03 large GMSs have been observed and rate of increasing of SSN is comparatively low in comparison of other passed solar cycles.

Long-term variability of sudden storm commencements (SSCs)

Yearly occurrences of SSCs with for solar cycle 21-24 are plotted in Figure 1. It is found that annually occurred value of SSCs follows with SSN during the period of solar cycle 22 and 23, but solar cycle 21 is exceptional among them. During the period of solar cycle 21, annual mean SSNs are as high as solar cycle 22, but number of occurred SSCs is less than other cycles. It is also observed that number of occurred SSCs is less during maximum of this cycle. These results indicate that it is not necessary that all fast solar eruptions caused the SSCs; it may differ from cycle to cycle. Out of selected large GMSs, 58% were associated with SSCs. We have also found that a number of SSCs have not been associated with any significant change in the D_{st} magnitude. It is also observed that, in most of the cases, the onset of main phase of GMS just follows SSC. For the selected SSCs associated GMSs, the most probable value of time difference between SSC and onset of main phase of GMSs is found to vary between 0-2 hr.

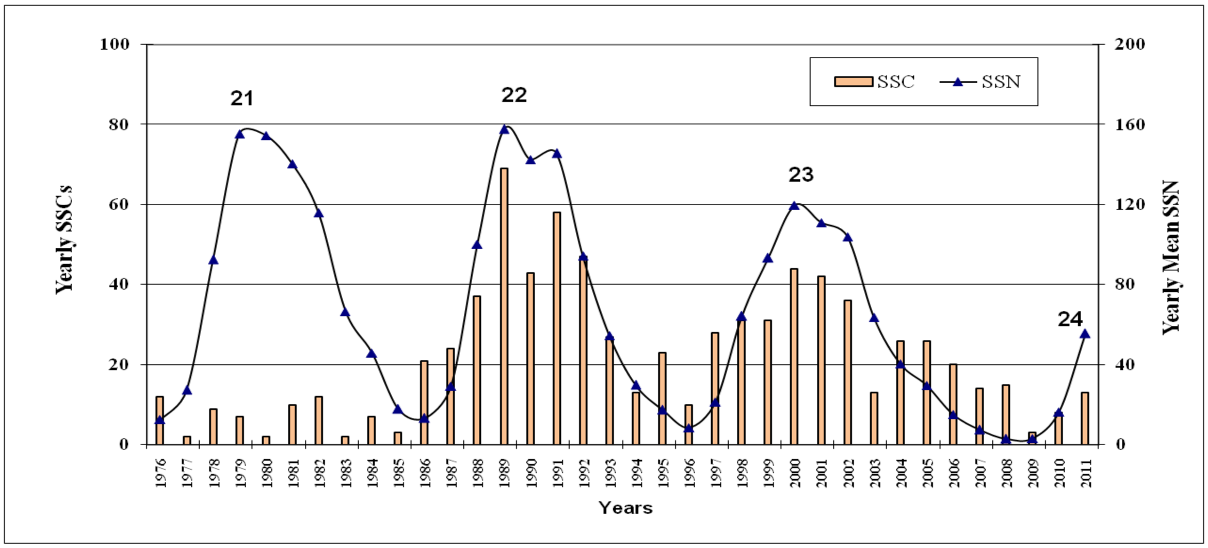

Figure 1: Shows the association of yearly occurrence of SSCs with yearly mean SSN, observed during the period 1976-2011.

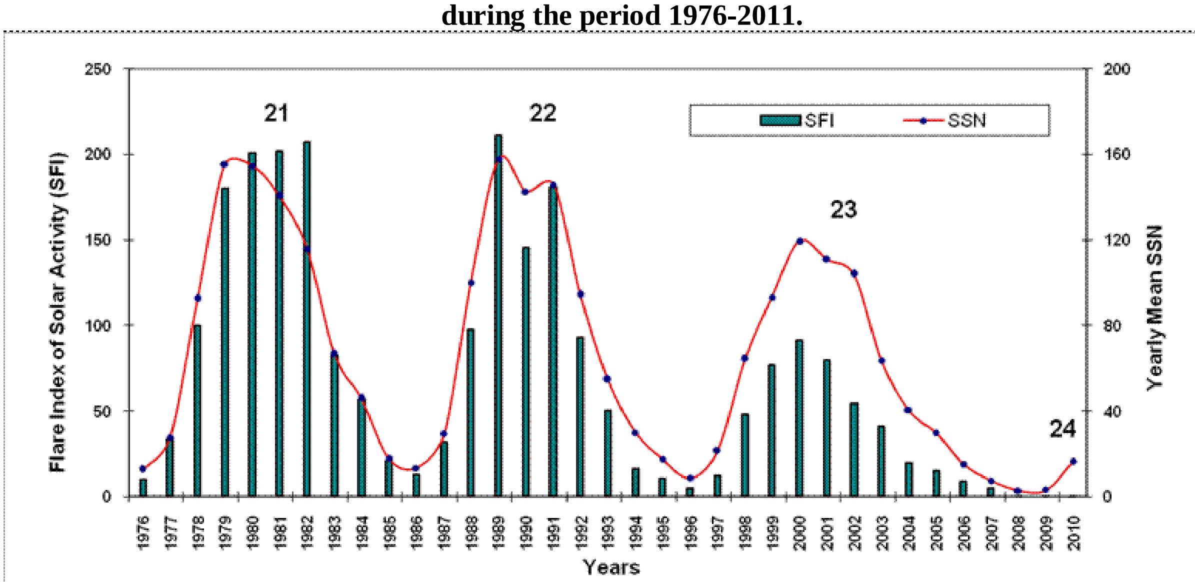

Figure 2: Shows the association of flare index of solar activity (SFI) and their association with 11-year sunspot cycle, observed during the period 1976-2011.

International Journal of Physics and Mathematical Sciences ISSN: 2277-2111 (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jpms.htm
2015 Vol. 5 (1) January-March, pp. 35-41/Dubey and Pandey
Research Article

Long-term variability of solar flare index (SFI)

The long-term variations of Kleczek SFI with annual mean SSN for the period 1976-2007 are plotted in Figure 2. We find that the yearly occurred value of SFI varies with 11-year sunspot cycle except at some circumstances, but overall behaviours are as similar as variation of solar transients.

Long-term variability of solar radio flux (SRF)

The long-term variation of SRF with SSN for the period 1976-2011, is plotted in Figure 3. We find that the yearly occurred value of SRF varies with 11-year sunspot cycle as similar as variation of solar transients. A difference between the first and second maxima for solar cycle on the one hand and SRF on the other is intriguing. If the radio emission is associated with sunspots, the relative values of the first and second maximum should be similar, at least qualitatively, for both. However, decimetric frequencies would be from bremsstrahlung and may not follow sunspots.

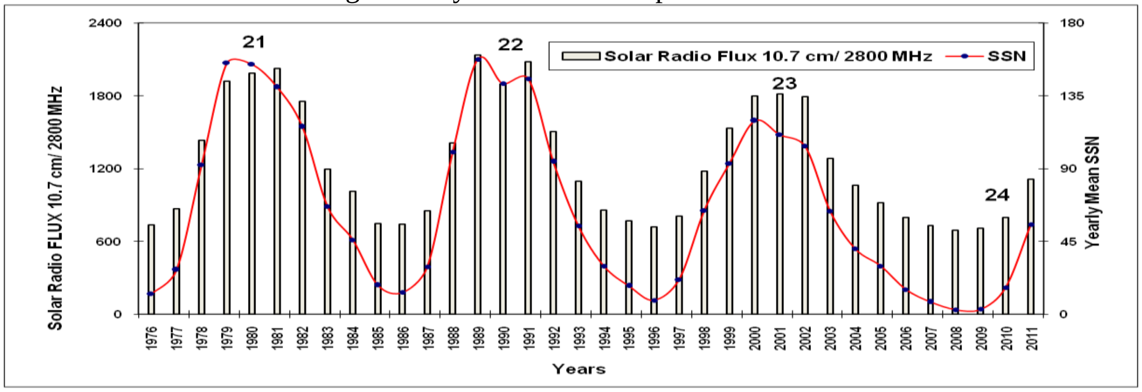

Figure 3: Shows the association of solar radio flux 10.7 cm/2800 MHz and their association with 11-year sunspot cycle, observed during the period 1976-2011.

Long-term variability of solar energetic particle (SEP) events

The solar energetic particle (SEP) events are the energetic outbursts as a result of acceleration and heating of solar plasma during SFs and CMEs. SEP events associated with SFs are called impulsive where as those associated with CMEs are gradual. Occurrence of SEP events are varies with 11-year sunspot cycle. In the present section, we investigate the association of SEP events on long-term basis. An association of occurrence of SEP events (E ≥10 MeV) with 11-year sunspot cycle is plotted in Figure 4. We haven't shows very significant associations between the yearly occurrences of SEP events with 11-year sunspot cycle except solar cycle 22. SEP events are an important cause to produce geomagnetic and ionospheric disturbances on large scale. The more severe SEP events can cause widespread disruption to electrical grids.

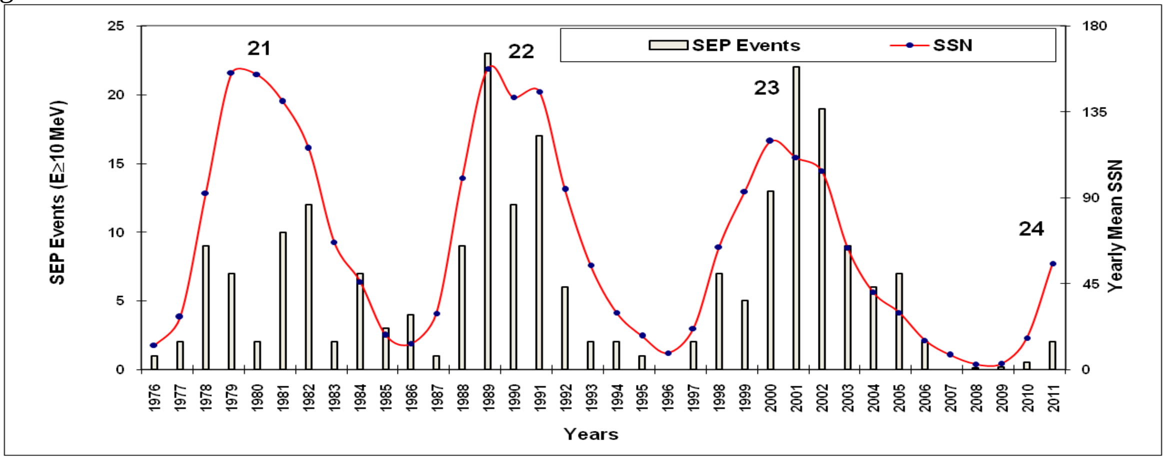

Figure 4: Shows the association of SEP Events (E ≥10 MeV) and their association with 11-year sunspot cycle, observed during the period 1976-2011.

Research Article

Long-term variability of total solar irradiance (TSI)

The total solar irradiance (TSI) is integrated solar energy flux over the entire spectrum which arrives at the top of the atmosphere at the mean Sun-Earth distance. The TSI observations show variations ranging from a few days up to the 11-year sunspot cycle and longer timescales (Kopp and Lean, 2011). TSI has been monitored from 1978 by several satellites, e.g. Nimbus 7, Solar Maximum Mission (SMM), the NASA, Earth Radiation Budget Satellite (ERBS), NOAA9, NOAA 10, Eureca and the UARS (Upper Atmospheric Research Satellite) etc. The historical reconstruction of more recently accepted TSI absolute value is described by Kopp and Lean (2011) based on new calibration and diagnostic measurements by using TIM V.12 data on 19th January 2012, and is updated annually. TSI are known to be linked to Earth climate and temperature. The historical reconstruction of TSI and their association with 11-year sunspot cycle from 1976 onwards are shown in Figure 5. From the plot, it is finding that TSI variation trend follows 11-year sunspot cycle within limit

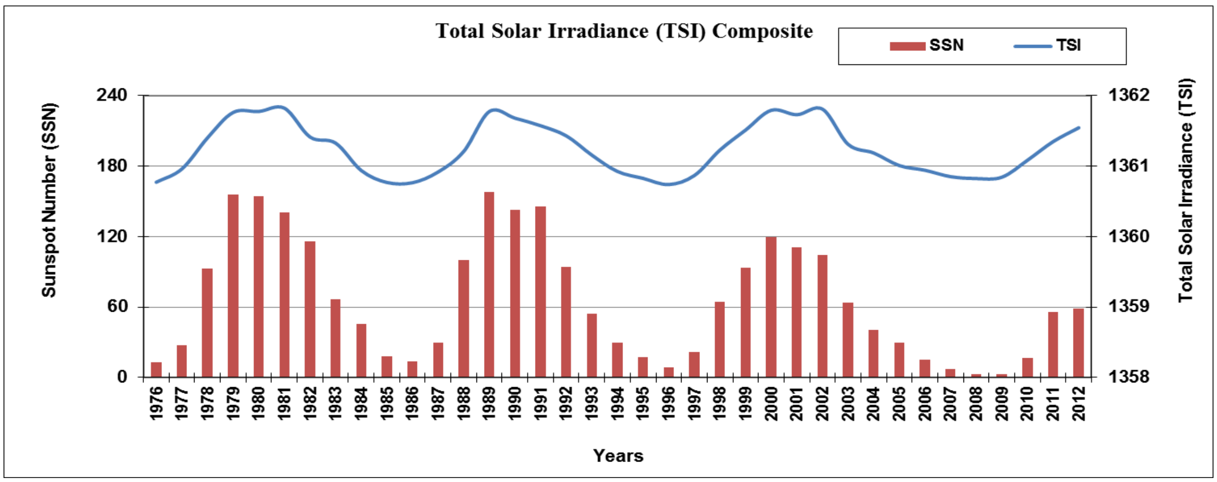

Figure 5: Shows the association of total solar irradiance (TSI) with 11-year sunspot cycle, observed during the period 1976-2012.

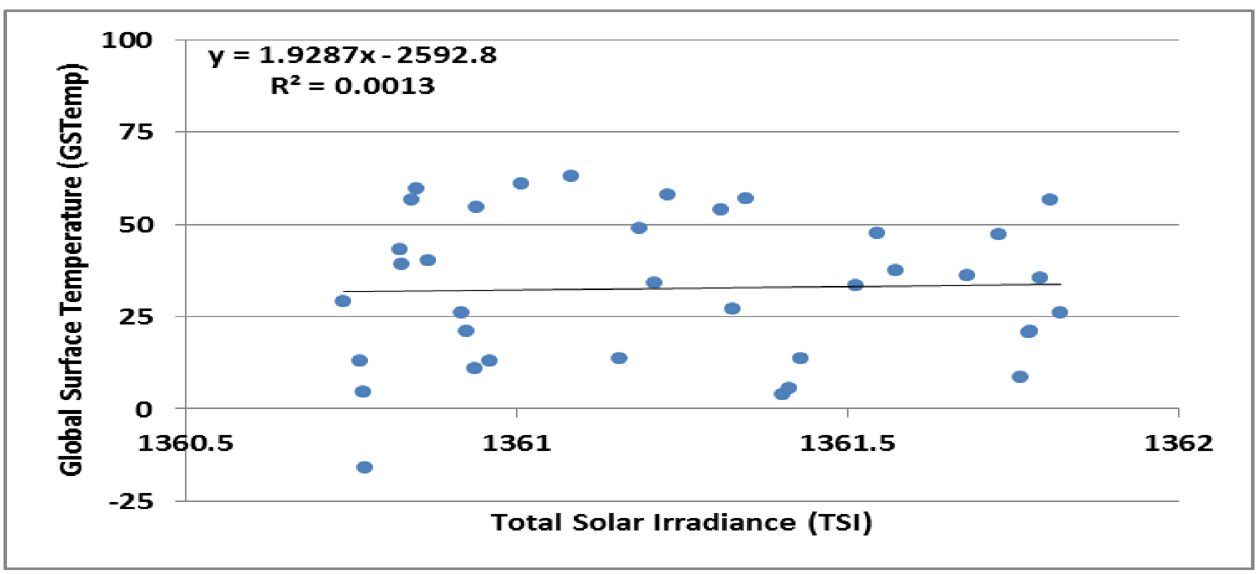

Figure 6: Scatter plot between yearly average value of total solar irradiance (TSI) and global surface temperature (GSTemp) during 1976 onwards.

International Journal of Physics and Mathematical Sciences ISSN: 2277-2111 (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jpms.htm
2015 Vol. 5 (1) January-March, pp. 35-41/Dubey and Pandey
Research Article

Long-term variability of total solar irradiance (TSI) and global surface temperature

The effect of global surface temperature is increasing the average temperature of the Earth. The basic causes of increase in global temperature can occur from variation in TSI and human made activities (mainly emission of Co_2). We have calculated correlation between total solar irradiance (TSI) and global surface temperature (GSTemp) during 1976 onwards is scatter plotted in Figure 6. We find a poor correlation (r=0.036) between them. Since 1978, the Sun has shown a slight cooling trend but global temperatures have been warmed up continuously. It is indication for a dangerous period and high awareness about global warming is most essential, otherwise we left our Earth as flame of burning for next generation.

Solar activities and global climate change

The solar activities, galactic cosmic rays, interstellar dust and Sun-Earth geometry have strong influence on climate and can increase concentration of greenhouse gases. The world has warmed 0.74°C in the past hundred years due to increases in greenhouse gas concentrations. Global average temperature is forecast to rise 4°C (7.2°F) toward the end of the 21st century. A rise in Earth's global temperatures may boost the occurrence and concentration of severe climate events, such as floods, famines, heat waves, tornados, and twisters. Other consequences may comprise of higher or lower agricultural outputs, glacier melting, lesser summer stream flows, genus extinctions and rise in the ranges of disease vectors. As an effect of increase in global surface temperature species like golden toad, harlequin frog of Costa Rica has already become extinct. There are number of species that have a threat of disappearing soon and various new diseases have emerged lately. The increase in global surface temperature is extending the distribution of mosquitoes due to the increase in humidity levels and their frequent growth in warmer atmosphere. Various diseases due to ebola, hanta and machupo virus are expected due to warmer climates. The effect of increase in global surface temperature will definitely be seen on some species in the water. The increase in global surface temperature is expected to cause irreversible changes in the ecosystem and the behavior of animals. Based on the study on past climate shifts and computer simulations, many climate scientists say that lacking of big curbs in greenhouse gas discharges, the 21st century might see temperatures rise of about 3 to 8º C, climate patterns piercingly shift, ice sheets contract and seas rise several feet. Climate change will exert unprecedented stress on the coastal and marine environment too. Increase in ocean temperature cause sea level rise and will have impact on ocean circulation patterns, ice cover, fresh water run-off, salinity, oxygen levels and water acidity. Sea level is rising around the world. In the last century, sea level rose 5 to 6 inches more than the global average along the Mid-Atlantic and Gulf Coasts, because coastal lands there are subsiding. Due to global warming, higher temperatures are expected to further raise sea level by expanding ocean water, melting mountain glaciers and small ice caps, and causing portions of Greenland and the Antarctic ice sheets to melt. If sea level rise could convert as much as 33% of the world's coastal wetlands to open water by 21st century. Forecasts of climate extremes can improve awareness and reduce adverse effects. Focusing attention on extreme events also may help countries to develop better means of dealing with the longer-term impacts of global climate change. Conversely, the pressures on the biosphere that drive climate change may cause critical thresholds to be breached, leading to shifts in natural systems that are unforeseen and rapid. Studying historical extremes of climate cannot forewarn on the consequences of such events. Rapid changes in climate during extreme events may be more stressful than slowly developing changes due to the greenhouse effect.

Conclusions

During the period (1997-2011), we have found 93 large GMSs that are associated with D_{st} decreases of more than 100 nT. Out of selected 93 large GMSs, 54 are sudden commencement type and rests 39 are gradual commencement type. Yearly occurrence of above mentioned GMSs have no significant correlation between the maximum and minimum phases for solar cycle. It is also find that occurrence of large GMSs during its declining phase of solar cycle 23 is higher and shows controversial result measured at yet. During passed periods of solar cycle 24, only 03 large GMSs have been observed and rate of increasing of SSN is comparatively low in comparison of other passed solar cycles.

The long-term variation of SSCs for solar cycle 21-24 shows that annually occurred value of SSCs follows with SSN during the period of solar cycle 22 and 23, but solar cycle 21 is exceptional among them. During the period of solar cycle 21, annual mean SSNs are as high as solar cycle 22, but number of occurred SSCs is less than other cycles. It is also observed that number of occurred SSCs is less during maximum of this cycle.

The long-term variation of Kleczek SFI with annual mean SSN for the period 1976-2007 shows that the yearly occurred value of SFI varies with 11-year sunspot cycle except at some circumstances and overall behaviours are as similar as variation of other solar transients.

The long-term variation of SRF with annual mean SSN for the period 1976-2011, shows that the yearly occurred value of SRF varies with 11-year sunspot cycle as similar as variation of other solar transients. A difference between the first and second maxima for solar cycle on the one hand and SRF on the other is intriguing.

Association of occurrence of SEP events ($E \geq 10$ MeV) with 11-year sunspot cycle haven't shows very significant associations between the yearly occurrences of SEP events with solar cycle except solar cycle 22. SEP events are an important cause to produce geomagnetic and ionospheric disturbances on large scale. The more severe SEP events can cause widespread disruption to electrical grids

The long-term solar irradiance variations might contribute to global warming over decades or hundreds of years. Some of these changes are particularly small shifts in the length of the solar activity cycle. Sun has shown a slight cooling trend since 1960, over the same period that global temperatures have been warm. It is indication for a dangerous period and high awareness about global warming.

REFERENCES

Joselyn JA and McIntosh PS (1981). Disappearing solar filaments: A useful predictor of geomagnetic activity. *Journal of Geophysical Research* **86** 4455.

Tousey R (1973). The solar corona. *Space Research* **13(2)** 713.

Gosling JT (1993). The solar flare myth. *Journal of Geophysical Research* **98 (A11)** 18937-18949.

Dubey SC (1998). Coronal mass ejection and their geoeffectiveness. *Indian Journal of Radio Space Physics* **27** 43-46.

Pandey SK and Dubey SC (2009). Characteristic features of large geomagnetic storms observed during solar cycle 23. *Indian Journal of Radio Space Physics* **38** 305-312.

Howard RA, Sheeley N R (Jr), Kooman M J and Michels DJ (1985). Coronal mass ejections: 1979–1981. *Journal of Geophysical Research* **90(A9)** 8173-8191.

Gopalswamy N, Yashiro S and Akiyama S (2007). Geoeffectiveness of halo coronal mass ejections. *Journal of Geophysical Research* **112(A06112)** 1-13.

J Kleczek J (1952). Solar flare index calculations. *Publ. Centr. Astron. Inst. Czechoslovakia*, **22** Prague.

Sugiura, M (1964). Hourly values of equatorial D_{st} for IGY. *Annals International Geophysics* **35 (I)** 9-45.

Kopp G and Lean JL (2011). A New, Lower Value of Total Solar Irradiance: Evidence and Climate Significance, *Geophysics Research Letters Frontier article* **38** L01706.