29th International Cosmic Ray Conference Pune (2005) **2**, 311–314

Anti-podal Geomagnetic activity, Sea surface temperature and long-term solar variations

G. N. Shah and S. Mufti
Nuclear Research Laboratory, Bhabha Atomic Research Centre, Srinagar - 190 006, India
Presenter: G. N. Shah (drgnshah@rediffmail.com), ind-shah-GN-abs2-sh35-poster

Geomagnetic activity indices reflect variations in the solar wind plasma and solar activity parameters. Variations in these parameters have a pronounced effect on the cosmic ray intensity observed on the earth, which in turn could be of consequence in some of the geophysical processes. In the study presented here antipodal geomagnetic activity indices and global sea surface temperature data over more than a century have been utilized to study the variations in these indices. Existence of a unique long-term variation in SST and between the difference in antipodal geomagnetic activity indices (i.e. Asymmetry) is presented in this study. Together with the power spectrum analysis of the asymmetry parameter various periodicities are revealed in the analysis. The observed variations suggest long term variations in the solar output which could be linked to the principal 11-year sunspot cycle, 22-year Hale magnetic cycle and long term Gleissberg's cycle. The results suggest a long-term solar variability and indicate long term solar influence on various terrestrial parameters.

1. Introduction

The solar activity has been shown to vary over periods of 11 and 22 years as reflected in the cyclic variation in the sunspot numbers and associated magnetic fields [1]. In addition long period solar cycle of 80-110 years has been inferred from various studies [2, 3, 4, 5, 6, 7]. The driving force behind various terrestrial phenomena like geomagnetic storms, auroral and weather systems etc. originate from the sun and the variations in it as reflected through sunspot numbers, solar flares, solar irradiance, interplanetary plasma, magnetic field variations and high energy solar particle events effect such phenomena [8, 9, 10, 11, 12]. Since climatic changes on earth have become of great concern it is pertinent to explore whether the long period solar variations also reflect in the variations of the climatic parameters. Further, it is also important to explore whether any such climatic variations have a linkage with the geomagnetic activity.

2. Data used

The following data were used for this work:

i) We have chosen more than a century of the (aa) antipodal geomagnetic indices data, which is the continuation of the series beginning in the year 1868. A full description of these indices is given in the IAGA Bulletin 33 [13]. Briefly, the three-hourly aa indices computed from the k-indices of two antipodal observatories (invariant magnetic latitude 50 °) provide a quantitative characterization of the magnetic activity, which is homogeneous through the whole series. The aa indices are available from the appropriate World Data Centers in digital form using the format described in IAGA Bulletin No. 33.

ii) We have chosen the global sea surface temperature as a representative of the climatic parameter in the present study. The sea surface temperature in many ways is a better measure of global climate, since it represents over 70% of the planet's surface area, and is much more spatially and temporally homogeneous than the land surface. The data is also free from potential problems such as urban warming. The utilized data consists of about 40 million quality controlled values for the period 1856 to 1987 [14, 15].

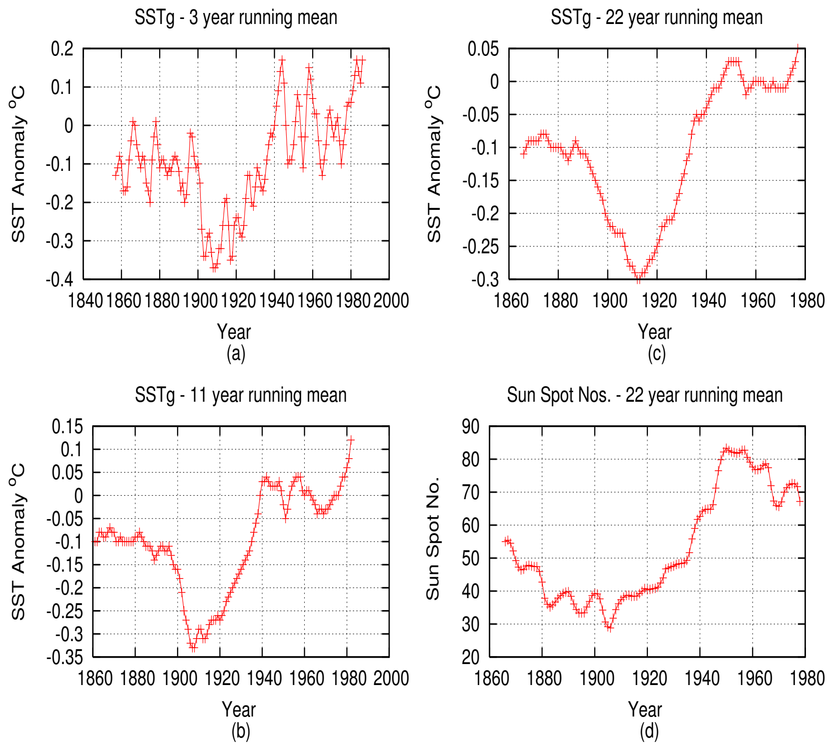

Figure 1. (a) 3 year running mean - SStg. (b) 11 year running mean - SSTg. (c) 22 year running mean - SSTg. (d) 22 year running mean of sun spot numbers.

iii) The Wolf (or Zurich) sunspot number has been largely used to infer the long-term variability of the solar activity. The sunspot number time series was obtained from the sun spot index data center in Brussels, Belgium.

3. Data Analysis and Results

In figure. 1. (a) we plot the 3 year running mean of the yearly global sea surface temperature values (SSTg). The values of SSTg are seen to show a broad variation with a clear minimum near the beginning of the 20th century. This is brought out more clearly in figure 1. (b) and (c) wherein we plot 11 and 22 year running mean values of the global sea surface temperature (SSTg) to even out fluctuations on short time scales. The curves show a broad variation with a deep minimum near the year 1906. A cold decade is evident in the pattern close to Gleissberg's minimum [16]. In figure 1. (d) we show for the period 1856 to 1986 the 22 year running mean of the sun spot numbers. As is evident the sunspot activity also reaches a minimum around the same period as the SSTg . The minimum being the well recognized Gleissberg's minimum in solar activity.

In order to find a causative parameter of the long solar cycle in solar activity responsible for the observed climatic change we show in figure 2. (a) the asymmetry in the north-south geomagnetic activity [17] and its variation with solar cycle number. A deep minimum in cycle 14 is very clearly indicated. In figure 2. (b) the 22 year running mean values of the asymmetry and the SSTg are compared. A striking correspondence between the two curves is evident from the figure. Both the Asymmetry and global sea surface temperature

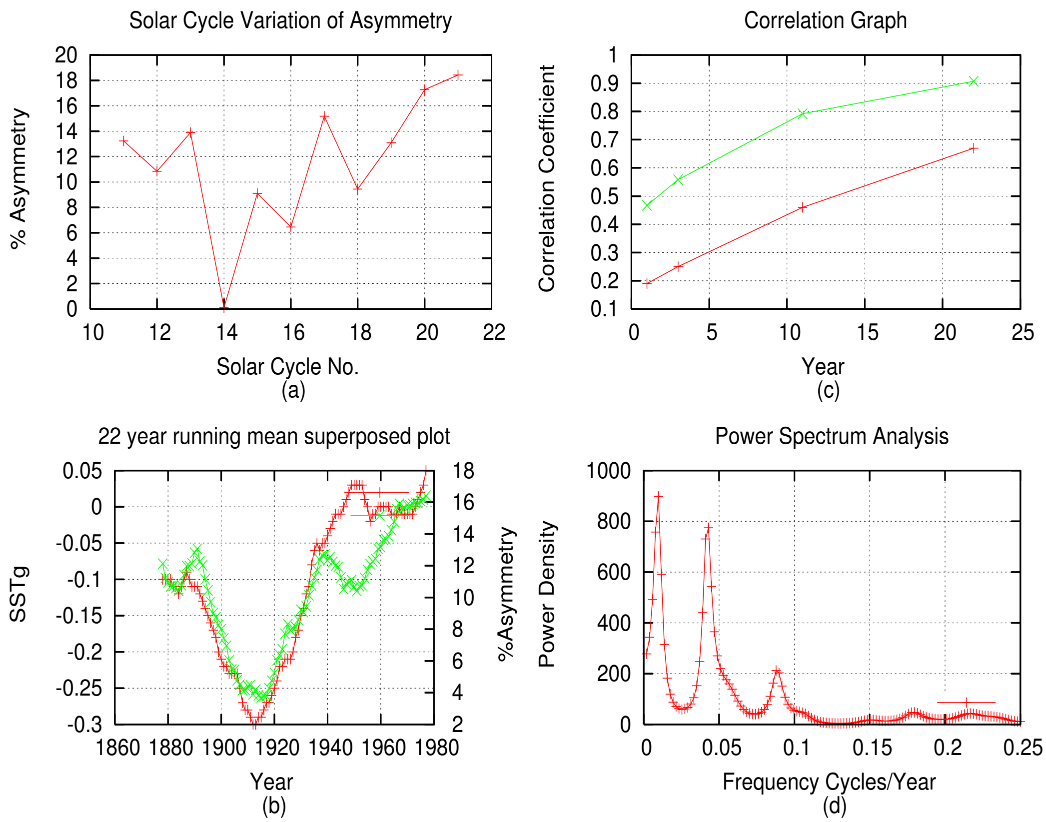

Figure 2. (a) Variation of geomagnetic asymmetry with solar cycle number. (b) 22 year running mean of SSTg and Asymmetry compared. (c) Correlation coefficient between asymmetry and Sunspot number (lower curve) and between SSTg and sunspot numbers (upper curve). (d) The power spectrum of the aa time series reveals 100, 23.8 and 11.3 year periodicities.

show a similar long term variation and both seem to be on the increase after reaching a minimum in the early twentieth century. The correlation coefficient between the SSTg and the asymmetry values is found to be 0.93. From figure 2 (c) it is noted that the SSTg and asymmetry are strongly correlated (upper curve) compared to asymmetry and sunspot number (lower curve). In figure 2. (d) is shown the power spectrum of the yearly asymmetry values for the period 1868 to 1987. The spectrum is based on the Maximum Entropy Method of Spectral analysis by J. P. Burg [18]. The analysis is based on short time series of 120 data points and makes use of a filter length of 40, which is in accordance with the suggestion of most authors not to go beyond 30 percent of the length of the time series to avoid spectral shifts [19]. The spectrum shows prominent peak periodicities of 100 years, 22.8 years, 11.3 years. The 22.8 year and 11.3 year periodicities indicate the influence of the Hale magnetic cycle and 11 years sunspot cycle on the asymmetry. The 100 year period seem to be related to the long term Gleissbergs cycle in solar activity. The strong correlation between the asymmetry and SST seen in conjunction with the 100 years observed periodicity suggest that we may soon be in for another minima in these parameters in the early 21st century. The correlation is found to be poor in 3 year and 11 year running mean data.

4. Conclusion

The results seem to indicate a broad change in the Global sea surface temperature with minimum coinciding with the Gleissbergs minimum in solar activity. Further, Geomagnetic activity seems to be the possible link through which the solar activity controls the earths climate. The investigations presented here are intended as a contribution to the current debate on the cause and effect phenomenon. We believe that the role of the sun in forcing the climatic change is still an open question.

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