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VARIATION IN NORTH-SOUTH ASYMMETRY OF SUN SPOT AREA

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ABSTRACT

The existence of the North-South asymmetry of the solar activity is widely accepted even though the phenomenon is not yet satisfactorily understood. We have studied the temporal variations in the North-South asymmetry of the sunspot area during the period from May in 1874 to April in 2007. The combined data have been examined for periodicity in the solar activity North-South asymmetry. We have found that (i) solar northern and southern hemispheres show an asymmetric behavior, in terms of a sunspot area, (ii) sunspot areas in northern and southern hemispheres show clearly the 11 year periodicity when they were analyzed separately, as they do when analyzed together, (iii) in addition to the general 11 year periodicity in both northern and southern hemisphere solar activities, there are also noticeable shorter periodicities other than the 11 year periodicity in the asymmetry in North-South activity. Finally, we conclude by pointing out the importance of studying the North-South asymmetry of the solar activity.

Keywords: sun: sunspot – methods: data analysis

1. INTRODUCTION

A periodic character of the solar activity is already well studied in great details. One of the most interesting properties of the solar activity is its North-South asymmetry, which is a second order effect in comparison with other solar activity indices. Existence of the North-South asymmetry in the solar activity has been demonstrated by several statistical studies for most of solar activity phenomena. Unfortunately, however, the cause of the North-South asymmetry of solar activity is not known so far.

The North-South asymmetries of several manifestations of solar activity have been studied earlier by various authors. White & Trotter (1977) published plots of the distribution of sunspots between the north and south solar hemispheres, using data of sunspot areas from 1874 to 1971. In their study plots show that the largest and most obvious variation has a period of about 11 years, and that north and south are approximately in phase with each other, and with the total sunspot number. From these results they have concluded that the solar magnetic cycle occurs uniformly in the north and south solar hemispheres. Roy (1977) has also examined the north-south distribution of major flares and sunspot area, and noted that the asymmetry does not appear to be connected with the 11 year cycle or to reflect the alternating predomination of spot activity between hemispheres with a 22 year period. Swinson, Koyama, & Saito (1986) also examined relative sunspot numbers and sunspot area.

Verma (1987) has claimed that several solar activity phenomena show some form of the North-South asymmetry. He has studied six types of solar phenomena, including major flares, type II radio bursts, white light flares, solar gamma-ray bursts, hard X-ray bursts and coronal mass ejection (CME) events. In addition, there are considerable North-South differences in the differential rotation rates and the meridional motions of sunspots (Javaraiah & Ulrich 2006). Helioseismology measurements also show the existence of North-South differences in the solar rotational and meridional flows (Zaatri et al. 2006). Therefore, the North-South asymmetry in the solar activity is an important physical solar property and it greatly helps for understanding variations in the solar activity. That is, a solar dynamo theory must explain this phenomenon. The prediction of the level of the activity is very much important because solar activity impact us in many ways. The North-South asymmetry may give us a clue in predicting the level of the solar activity (Hathaway & Wilson 2004, Javaraiah 2005). A strong correlation between northern activity and a cosmic-ray density gradient perpendicular to the ecliptic plane, which is evident in cosmic-ray diurnal variation data is also reported (e.g., Simpson, Zhang, & Bame 1996). It is well known that the terrestrial weather system is correlated with the cosmic ray density. Therefore, this kind of study is too crucial in understanding the long term variation of the terrestrial climate.

This paper begins with descriptions of the data and the analysis method in section 2. We present the data set we have used in this work, and discuss results on the periodicity we have obtained. Finally, we summarize and conclude in section 3.

2. DATA AND ANALYSIS

We have used for the present analysis the Greenwich sunspot group data during the period from 1874 to 1976, and the sunspot group data from the Solar Optical Observing Network (SOON) of the US Air Force (USAF)/ US National Oceanic and Atmospheric Administration (NOAA) during the period of from 1977 to 2007. The Royal Greenwich Observatory (RGO) in England has collected and compiled daily sunspot observations from a small network of observatories to produce a dataset of daily observations starting in May of 1874. The Royal Greenwich Observatory has quit maintaining this dataset in 1976 when the US Air Force started compiling data from its own Solar Optical Observing Network. This compilation has been continued with the help of the US National Oceanic and Atmospheric Administration with much of the same information being compiled through to the present.

We have taken recently updated data from the NASA website[1], which is managed by Hathaway and his colleagues in Marshall Space Flight Center. The entire sunspot dataset is available as ASCII text files containing records for individual years. Each file consists of records with information on individual sunspot groups for each day that sunspots were observed. Text files containing the monthly averages of the daily sunspot areas (in units of millionths of a hemisphere) are also available.

Periodical occurrences are computed by applying the periodogram analysis method by Lomb and Scargle (see Chang 2006), which is particularly appropriate for the analysis of unevenly-spaced data. This analysis method is basically same as Fourier analysis and sine curve fitting analysis. One of main advantages of this method is that the significance of a peak in the periodogram can be easily estimated, with a so-called false alarm probability (FAP).

Figure 1 shows monthly smoothed hemispheric sunspot areas from 1874 to 2007, as a function

[1] http : //solarscience.msfc.nasa.gov/greenwich.shtml

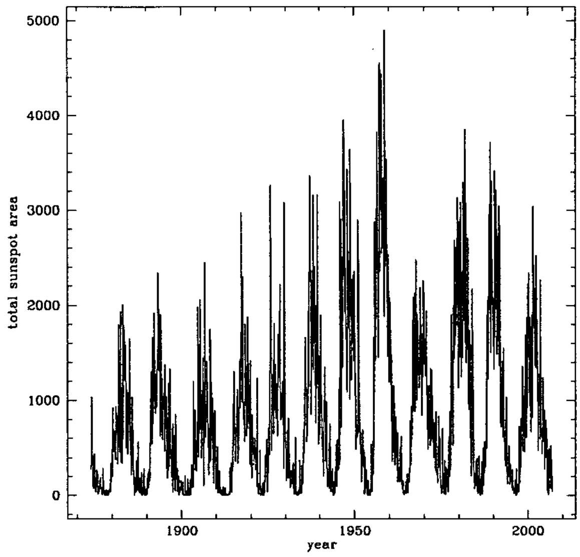

Figure 1. Monthly average of the total sunspot area for the period of 1874 – 2007, as a function of time.

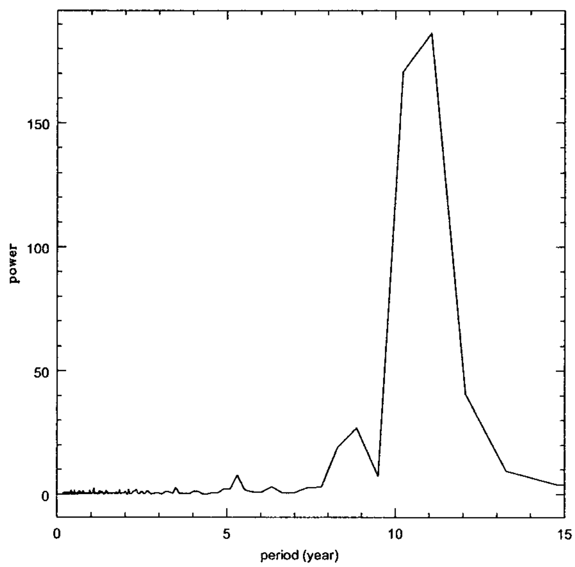

Figure 2. Lomb-Scargle periodogram of the total sunspot area for the period of 1874 – 2007.

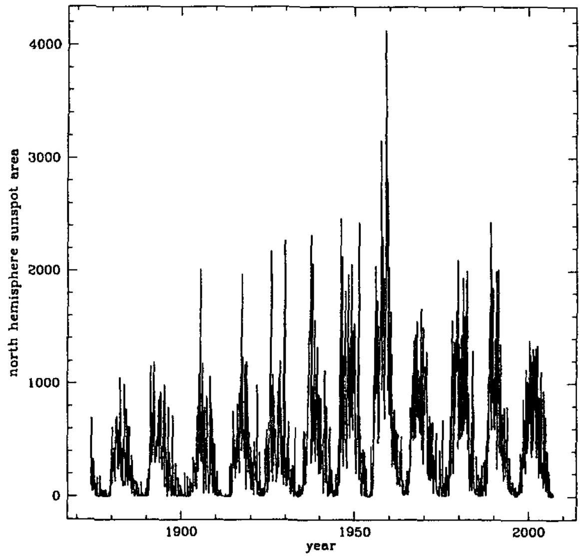

Figure 3. Monthly average of the sunspot area, which have appeared in the sun's northern hemisphere for the period of 1874 – 2007, as a function of time.

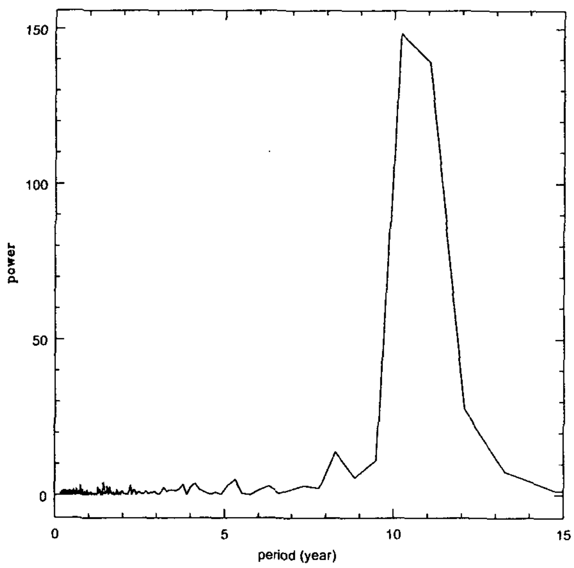

Figure 4. Lomb-Scargle periodogram of the sunspot area of northern hemisphere for the period of 1874 – 2007.

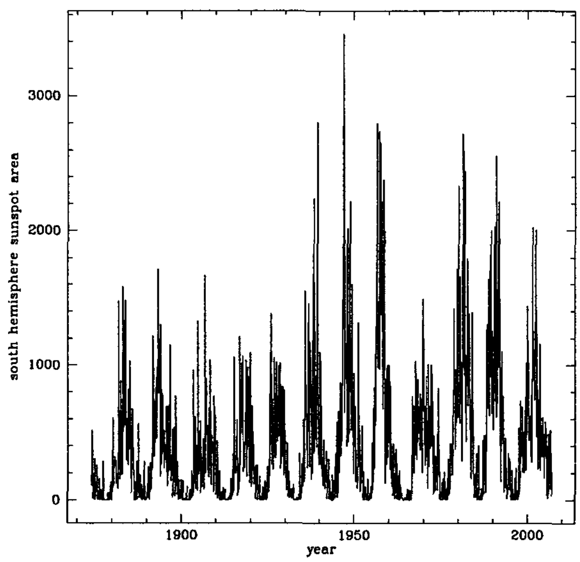

Figure 5. Monthly average of the sunspot area, which have appeared in the sun's southern hemisphere for the period of 1874 – 2007, as a function of time.

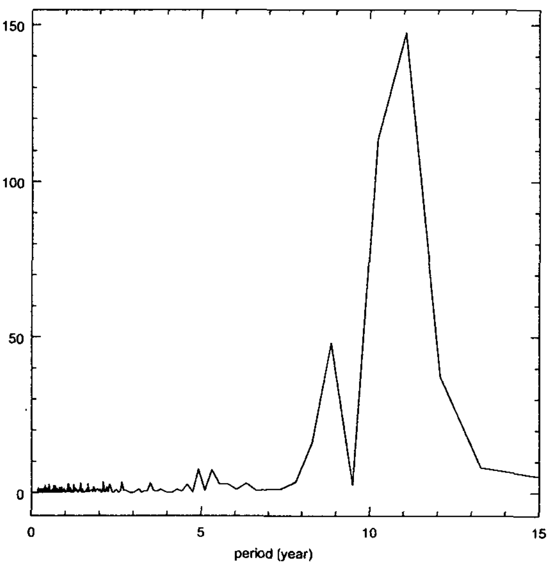

Figure 6. Lomb-Scargle periodogram of the sunspot area of southern hemisphere for the period of 1874 – 2007.

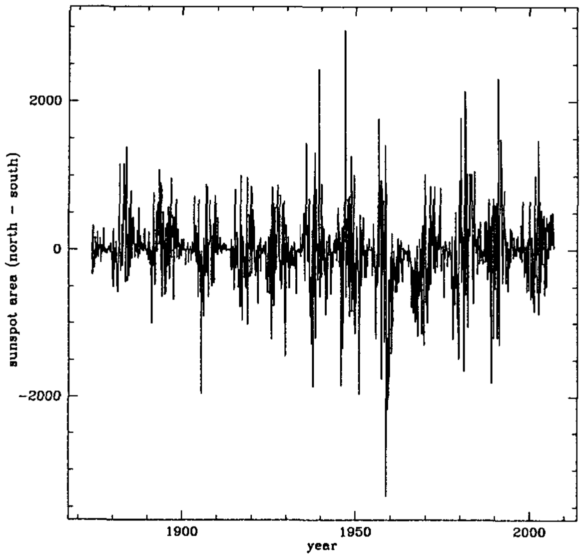

Figure 7. Difference between monthly average of the sunspot area of northern hemisphere and southern hemisphere for the period of 1874 – 2007, as a function of time.

of time. This plot includes solar cycles from 11 to 23, which is current one. It should be noted that, besides the 11 year solar cycle a secular and long term variation is also apparent. Figure 2 shows the Lomb-Scargle periodogram of the time series data shown in Figure 1. The 11 year periodicity is conspicuous. Figure 3 is a plot of monthly average of the sunspot area, which have been observed in the sun's northern hemisphere for the same period. Figure 4 shows the Lomb-Scargle periodogram of the time series data shown in Figure 3. Figure 5 is a plot of monthly average of the sunspot area, which have been observed in the sun's southern hemisphere for the same period. Figure 6 shows the Lomb-Scargle periodogram of the time series data shown in Figure 5. Both in Figures 4 and 6 the 11 year periodicity is conspicuous. Moreover, in comparison of Figures 3 and 5, one may notice that as the solar cycle proceeds the dominant hemisphere is alternating. In Figure 7, we show the difference of sunspot area between the northern hemisphere and the southern hemisphere. It is now clear that sunspot area is asymmetric. Amplitude of such an asymmetry varies during a solar cycle. Figure 8 shows the Lomb-Scargle periodogram of the time series of the difference. Note that the main periodicity of asymmetry does not coincide with the solar 11 year cycle. Interestingly enough, the main periodicity of asymmetry is $\sim$ 9. We also note that the main periodicity of the difference divided by total area is instead $\sim$ 12. Also, there exist a number of short-term periodicities, a few months to a few years, including $\sim$ 12 year periodicity.

3. SUMMARY AND CONCLUSION

We have studied the temporal variations in the North-South asymmetries of the sunspot area. In this present paper we have attempted to determine the periodicity in the temporal variation of the

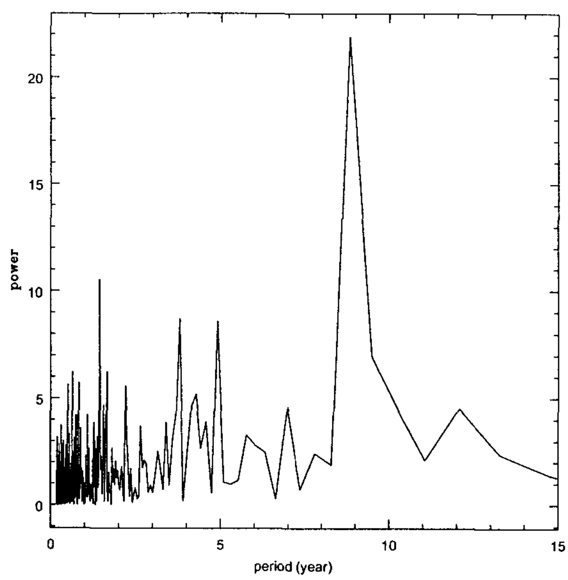

Figure 8. Lomb-Scargle periodogram of the difference between monthly average of the sunspot area of northern hemisphere and southern hemisphere for the period of 1874 – 2007.

North-South asymmetry in the solar sunspot areas. Using Greenwich and SOON sunspot group data during the period of 1874 – 2007 we find that:

(i) Two, northern and southern, hemispheres have an asymmetric behavior, in terms of a solar activity measure. It is clear that there are large variations both in the northern and in the southern sunspot area.

(ii) Sunspot areas in northern and southern hemispheres show the 11 year periodicity, when they were analyzed separately.

(iii) In addition to the general 11 year periodicity both in the northern and in the southern hemisphere solar activity, there are also noticeable shorter periodicities other than the 11 year periodicity in the asymmetry in the North-South activity.

To conclude, we should like to point out that:

(i) On these power spectra of the North-South asymmetry (1–5)-year periodicities are apparent. The nature of the North-South asymmetry of the different solar parameters is not clear until now. Any of the known solar dynamo mechanisms do not offer satisfying imagination on the asymmetrical global magnetic field structure. The North-South asymmetry of the field might be caused by a presence of the slowly varying fossil field.

(ii) The North-South asymmetry in the solar activity is an important physical solar property and it greatly helps for understanding variations in the solar activity. Particularly, the North-South asymmetry may give us a clue in predicting the level of the solar activity, as the space weather study requires.

(iii) A strong correlation between the northern activity and a cosmic-ray density gradient perpendicular to the ecliptic plane, which is evident in cosmic-ray diurnal variation data has been reported. It is well known that the terrestrial weather system is correlated with the cosmic ray density. Therefore, this kind of study is crucial in understanding the long term variation of the terrestrial climate.

(iv) Correlations with other solar activity measures and/or other solar structural parameters are to be sought as a next step study of the North-South asymmetry in the solar activity.

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