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# SOLAR WIND PARAMETERS AND RECORDS IN THE SUN-EARTH SYSTEM

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**ABSTRACT**

The variations of the solar wind in relation to carrying a southward component into the heliosphere may play a decisive role in some of the characteristics in all three records discussed here, galactic cosmic rays (GCRs), geomagnetic recurrence, and polar nitrate anomalies. In addition, it may be possible to gain a historic perspective on the record of GCRs by comparing the Climax neutron monitor data and the record of the geomagnetic recurrence index. The two sequences are the result of different physical mechanisms, but depend on the same solar parameters. Some of these parameters seem to play a role in ionization events leading to solar proton generated nitrate deposition in polar ice.

## 1 INTRODUCTION

It has been noted that some characteristics of the solar wind can be found in dissimilar records of geophysical and solar parameters (Dreschhoff and Zeller, in press). The striking similarity of the 22-year signal in galactic cosmic rays (GCRs) of sequential narrow-peaked and broad-peaked maxima can also be seen in the 27-day geomagnetic recurrence index. The physical mechanisms producing the signals are dissimilar and are related to the drift model (Jokipii, 1991) and southward component conditions of the interplanetary magnetic field (IMF), respectively. However, both processes depend on the same solar parameters in part related to the declining phase of the solar cycle and polarity epochs of the heliospheric magnetic configuration. The significance of the declining phase also has been recognized in a long-term record of ionization events in the polar stratosphere as measured by nitrate concentrations in the stratigraphic layers of the polar ice sheets. Data sequences comprise up to 430 years measured at ultra-high resolution making it possible to show the occurrence of such events (Shea et al., 1993; Zeller and Dreschhoff, 1995).

## 2 DATA

Figure 1(a) shows the intensities of galactic cosmic rays as measured by the Climax neutron monitor and anti-correlated with solar activity. The shape of the 22-year distribution shows the characteristic sequential flat-peaked and sharp-peaked maxima. Figure 1(b) shows the 27-day Bartel's rotation recurrence index (adapted from Sargent, 1985) of geomagnetic activity. The index has been plotted together with the monthly sunspot numbers indicating the 11-year anti-correlation as well. The feature of interest is the 22-year periodicity of narrow peaks and much wider peaks and displays a close resemblance with the GCR record. Figure 1(c) shows the distribution of excess sunspot areas of the sun in the northern hemisphere (black) and southern hemisphere (dotted) adapted from Shea et al., (1989). It has been suggested that there is a relationship between sustained hemispheric activity and a shift of the neutral current sheet away from the hemisphere of higher activity. Thus there would be a higher probability of a larger fraction of days with southward IMF components at the earth during positive polarity epochs of the general solar magnetic field (northern solar polarity positive) combined with an excess of activity in the northern hemisphere of the sun.

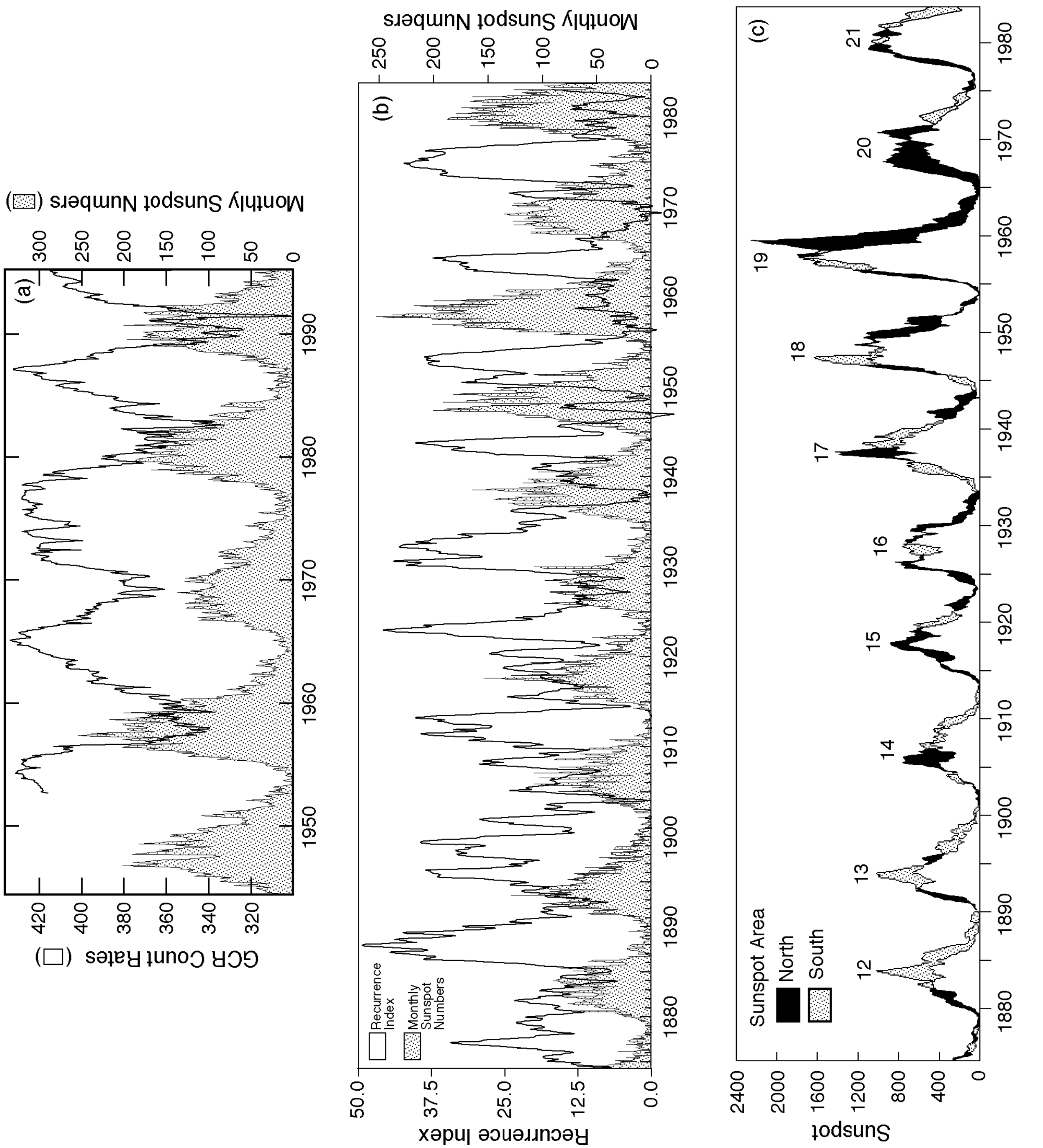


**Figure 1:** 1(a) Galactic cosmic ray record from the CLIMAX neutron monitor station shown together with the monthly sunspot numbers. The GCR signal displays the characteristic 22-year response with sequential flat peaked and sharp-peaked maxima. 1(b) The 27-day Bartels rotation-geomagnetic recurrence index adapted from Sargent, (1985). The record shows the 11-year and 22-year periodicities anti-correlated with solar activity plotted as monthly sunspot numbers. 1(c) Distribution of excess sunspot areas in the northern hemisphere (black) and southern hemisphere (dotted) of the sun adapted from Shea et al., (1989) and Swinson et al., (1991). The solar cycle numbers have been identified in Figure 1(c).

Another geophysical record related directly to solar proton induced ionization in the polar atmosphere, and indirectly to the declining phase and the southward component of the IMF, may provide a detailed long-term data sequence from solar cycle –3 to the present. The record consists of large (>2 σ) anomalies of nitrate concentrations preserved in the central ice sheet of Greenland (Zeller and Dreschhoff, 1995). They have been identified previously in Antarctic ice cores as resulting from high fluence solar proton events (>10 MeV; $>10^9$ p+ $cm^{-2}$) (Shea et al., 1993). In Figure 2(a) the total number of anomalies has been plotted per each solar cycle. The distribution clearly shows the increasing numbers toward the present. However, within each solar cycle the majority (~67%) tends to occur during the declining phase as shown in Figure 2(b). When separating this distribution relative to the negative (Figure 2(c)) and positive (Figure 2(d)) polarity epochs of the solar dipole field (projecting the reversals back to cycle –3), it is found that the latter differs dramatically from all others by showing an almost bimodal distribution. Positive polarity tends to favor higher probabilities for southward components at the earth particularly for more activity in the northern hemisphere, thereby favoring the solar-terrestrial signal development as seen by the nitrate signal in the polar ice sheets.

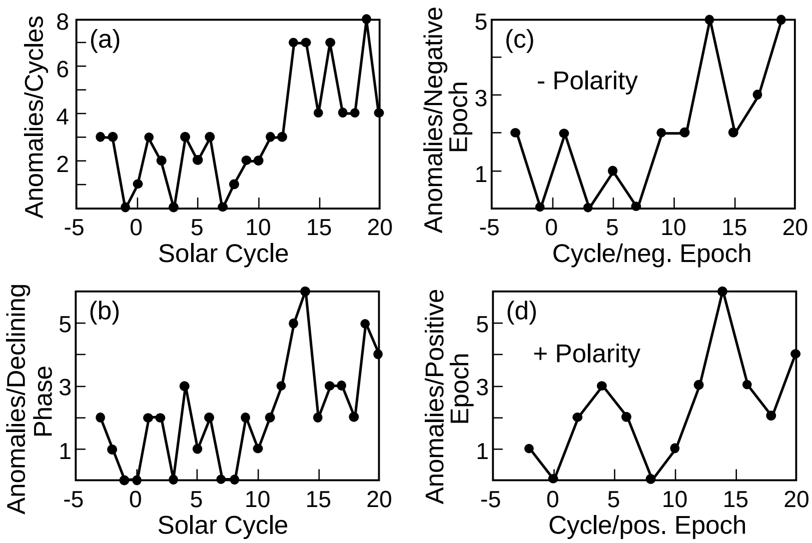


**Figure 2:** Major nitrate anomalies result from individual ionization events in the polar atmosphere induced by major solar proton events. 2(a) Total number of >2σ nitrate anomalies per solar cycle, 2(b) Number of >2σ anomalies during the declining phase (~67% of total number), 2(c) and 2(d) Number of 2σ anomalies during the declining phase and solar dipole configuration negative and positive, respectively.

# 3 DISCUSSION

Particular phases of the solar cycle in combination with the magnetic configuration in the inner heliosphere may have a distinct influence on the geoeffectiveness of some solar processes. This results in the 22-year modulation of the GCR signal and the recurrence index of geomagnetic activity. Both records show a similar 22-year response, the universal parameter being the solar wind. If we make the assumption that these similarities can be extended backward in time for the relative intensities of the GCRs, it would also include the discontinuity appearing in the recurrence index around ~1900±15 years during solar maximum periods. The recurrence index undergoes a variation that can be described as a breakdown in the 11-year response at sunspot maximum approximately between 1880 and 1920 (Sargent, 1985). The significance of this time period may be deduced in conjunction with the other solar or geophysical records. It is noted that this period of time was also accompanied by a change in the spatial distribution of activity as seen on the surface of the sun. The north/south asymmetry of solar activity changes from a period of sustained south-hemisphere activity to more equally varying between both hemispheres (Figure 1(c)). The bimodal distribution of polar nitrate anomalies shows a major shift in the number of ionization events or solar proton events around the turn of the century (Figure 2(d)). Of particular interest are the large ionization events, which have been identified in the stratigraphic snow layers of the late 1800's. The anomalies detected at that time were also of exceptional strength or amplitude. These conspicuous occurrences coincide with similarly large peaks in high-resolution cosmogenic data, which consist of the high frequency components of secular variations of atmospheric $^{14}C$ (Damon and Perristykh, pers. com.,1996). Although the time period of solar cycle 13 is not characterized by particularly high sunspot numbers, it coincides with discontinuities in the temporal distribution of the recurrence index and hemispheric sunspot areas.

This time period can be analyzed further by comparing the number of years between each maximum of annual sunspot numbers and annual aa index from cycle 11 to 22. The shift of the aa index maximum (cycle 12 and 13) from preceding to following the sunspot maximum is clearly seen in Figure 3, which shows the temporal relationship between the two parameters as Δ (Delta) years for each sunspot cycle. It may be concluded that during that period the ascending phase of the solar cycle was dominant in producing magnetic storms on earth. This would indicate that coronal mass ejections (CMEs) during the ascending phases were dominant over high-speed streams in association with coronal hole development which are mostly a feature of the declining phases. Recent results mostly from spacecraft seem to be a confirmation of these observations, particularly relative to the critical role played by the declining phase in solar-terrestrial interactions. During the declining phase and at solar minimum enhanced solar wind flows can be associated with solar coronal holes, which persist for long periods of time and give rise to recurrent geomagnetic disturbances (Joselyn et al., 1997).

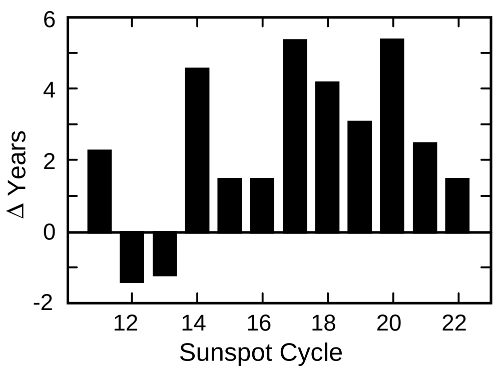


**Figure 3:** Temporal relationship of the yearly sunspot numbers at maximum to the maximum of the annual geomagnetic aa index plotted as Δ (Delta) Years or ±deviations. The deviations undergo a phase shift during cycles 12 and 13.

Whereas major magnetic storms, recurrent and non-recurrent, are the result of the combined effects of CMEs and co-rotating interaction regions (CIRs), the geoeffectiveness of the CIRs is strongly modified by the long-term evolution of the coronal holes (McAllister and Crooker, 1997). On the other hand, although CMEs are mostly responsible for non-recurrent storms, some recurrent storms are enhanced by solar wind disturbances produced by CMEs, where a strong southward interplanetary magnetic field (IMF) is crucial for stimulating geomagnetic activity (Gosling, 1997). Processes that lead to favorable conditions in terms of their geoeffectiveness such as recurrent magnetic storms, would also be advantageous for producing ionization events in the polar atmosphere to be detected as nitrate anomalies in ice layers.

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