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Hysteresis Loop Effect on Coronal Index and Solar Flare Index During Solar Cycles 22 and 23

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The hysteresis loop effect on the solar activity as coronal index (CI) and solar flare index (SFI) over cosmic ray intensity (CRI) at the low cut-off rigidities neutron monitoring station Oulu on the monthly basis data for the period January 1, 1986 to December 31, 2008 has been studied. It is observed that the shape of the hysteresis loops is varying from solar cycle 22 to 23. The hysteresis loops for solar cycle 23 are broad ovals whereas for solar cycle 22 are nearly flat. A complementary feature of the cosmic ray intensity decreases more rapidly as the increase in solar activity (coronal index and solar flare index). The positive solar polar magnetic parameter (A>0) and negative solar polar magnetic parameter (A<0) is representing the hysteresis loops.

Keywords: Solar activity (coronal index and solar flare index), Cosmic rays (Oulu)

Introduction

The long-term behavior of cosmic ray intensity can be explained on the basis of the hysteresis loop. This type of loop is providing the information regarding the large-scale structure of the heliospheric magnetic field. Stoker and Moraal[1] have studied the hysteresis loop in a long-term variation of cosmic ray intensity with solar activity and include the minimum and maximum phases of solar cycles[2-5]. The behavior of hysteresis loop modulations are generally two types first is a gradual moderate change in cosmic rays and second is a transient change in cosmic rays[6].

Stoker[7] showed the step-like changes are cosmic ray modulation in the hysteresis curve for the different phases of the sunspot cycle. Thus, the solar parameters are originating from a wide range of altitudes, for the most similar hysteresis models, although small differences exist. The propagation of shock waves in the interplanetary medium can be studied on the basis of the hysteresis loop.

Methods of Data Analysis

The absolute area of a modulation loop is the product of the quantity (Smax - Smin) and the average horizontal width of the loop; where Smax and Smin indicate the maximum and minimum value of CI and SFI during each solar cycle 22 and 23.It is observed that there is a difference between the modulation of loops for cycle 22 and cycle 23. The monthly pressure-corrected data of cosmic ray intensity (CRI) are available for the period January 1986 - December 2008 during solar cycles 22 to23at the low cut-off rigidities of neutron monitoring station Oulu (~0.85GV, 65.05°N, 25.47°E, http://cosmicrays.oulu/readme.html). The data corresponding to the coronal index (CI) and solar flare index (SFI) taken from the database of NGDC (http:// ngdc.gov.in).

Results and Discussion

The hysteresis loop between cosmic ray intensity (CRI) versus coronal index (CI) for even and odd solar cycles (for the two successive solar cycles 22 (1987-1996), and 23 (1996-2008)) see Fig. 1. The hysteresis loop of CRI with CI is wide in the odd cycle and narrow in the even cycle. From Fig.1, the hysteresis loop of solid line shows the positive solar polar magnetic parameter (A>0) and dashed line shows the negative solar polar magnetic parameter (A<0).

The hysteresis loop plots for cosmic ray intensity (CRI) versus solar flare index (SFI), for the two successive cycles 22 (1987-1996), and 23 (1996-2008) are shown in Fig. 2. It is observed that the hysteresis loop of CRI with SFI is wide in the odd cycle and narrow in the even cycle and it is representing two different types of the loop. From

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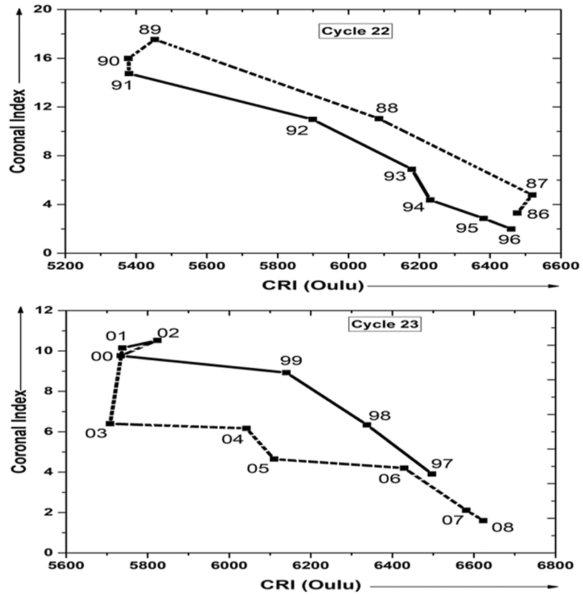

Fig. 1 – Hysteresis plots of CRI at Oulu NM station versus coronal index (CI), for solar cycle 22 (upper panel) and for cycle 23 (bottom panel).

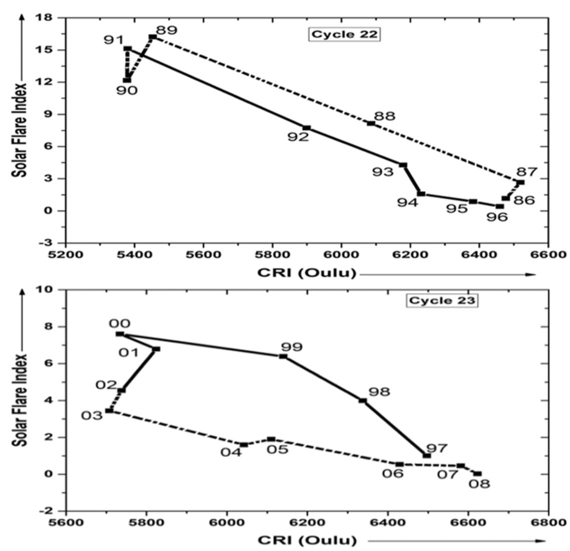

Fig. 2 – Hysteresis plots of CRI at Oulu NM station versus solar flare index (SFI), for solar cycle 22 (upper panel) and for cycle 23 (bottom panel).

Fig. 2, the loop of CRI versus SFI, solid line shows the positive solar polar magnetic parameter (A>0) and dashed line shows the negative solar polar magnetic parameter (A<0). However, loops are not clear for solar cycles 23 which represent odd solar cycles. These results indicate significantly the odd-even hypothesis in long-term cosmic ray intensity variation for the period of 1986 to 2008.

Table 1 – Measure of hysteresis loops during solar cycles 22-24.

Parameter/ Cycle	Area (SS)(ch^{-1})	Width (ch^{-1})/100
CI		
Cycle 22	3281.04	1141
Cycle 23	2253.99	915
SFI		
Cycle 22	2991.32	1141
Cycle 23	2855.34	915

We have noticed from the comparison of these diagrams that the odd solar cycles 23 show a clockwise vibrational trend. On the other hand, anti-clockwise variations are seen for even cycles 22. Formation of the hysteresis loops also shows odd-even symmetry in cosmic ray modulation. The comparison between these is given in Table 1, which includes the areas of the loops. On the basis of Table 1, the area of CI is larger as compared to SFI during even cycle 22 but in odd cycle 23 as the reverse. The width of CI and SFI is same during solar cycle 22 and 23, respectively. The positive solar polar magnetic parameter (A>0) is representing the northern hemispheric dipolar magnetic field. In this case, the original drift theory seems to indicate that cosmic ray access to the inner heliosphere and occur mainly on both magnetic poles. Such equatorial drifts are outward near the equator and thus increase the effect of outside convective transport centres of diffusion. The negative solar polar magnetic parameter (A<0) is representing the southern hemispheric dipolar magnetic field[8,9]. In this case, the drift particle predicts that access of cosmic rays to the inner magnetosphere occurs preferentially near the equator. Near equatorial drift are in the interior, so that they tend to cancel or exceed the effect of outside convective transport scattering centres by the solar wind.

Conclusions

The hysteresis plots of CR with respect to the solar parameters CI and SFI showed narrow loops in even cycles 22, and a wide loop on odd cycle 23. The cyclic variation in solar activity is representing odd and even cycles.

It is also found that the odd solar cycles show a clockwise trend, while the anticlockwise vibrational trend in even cycles. The different types of loop nature of odd and even solar cycles support the theory of odd-even hypothesis. The solid lines indicate the periods during which the solarpolar magnetic parameter A is positive and the dashed lines the periods during which A is negative in Figs 1 and 2. From Table 1, it is clear that the area of CI is larger as compared to SFI during even cycle 22 and width is the same in both solar cycles 22 and 23, respectively.

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