Long-term pattern in time lag of cosmic ray intensity

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***Abstract*. We have utilized four solar cycle data of cosmic ray intensity (CRI), sunspot number (SSN), geomagnetic index (aa), tilt angle of the heliospheric current sheet (TA), and interplanetary magnetic field (B). We studied the time lag between CRI and these solar/geomagnetic/interplanetary parameters during different solar activity levels (low and high) and solar magnetic polarities (A>0 and A<0). We find that solar and geomagnetic parameters offer different time lags with CRI. Although with different degree of correlations, we find that there is no time lag between CRI and B and between CRI and aa index even in different solar and magnetic conditions. We observe that the time lag between CRI and solar parameter (SSN) is much smaller during A>0 than A<0 epoch. But the time lag between CRI and TA is larger in positive polarity periods.**

***Keywords*: Long term variations, time lag, solar activity.**

I. Introduction

The CR modulation depth observed at the earth is a result of the combined action of solar and heliospheric conditions that control the CR behaviour all over the heliomagnetosphere. The delay of the CR effects relative to processes in the sun (hysteresis of CR) has been known since long ago (see [1] and references therein). The investigation of the hysteresis phenomenon between long-term variations in CRI, observed at the earth, and solar activity started many years ago ([2], [3]). The lag has been used earlier to estimate the radius of CR modulation region. Early estimates, based on comparison with coronal green line or by examining CR modulation caused by sudden jumps in solar activity indicated that the radius was very small, about 5 AU, not more than 10-15 AU. Dorman [4] used a convection-diffusion model, taking into account the time lag of processes in the interplanetary space relative to the processes on the sun and concluded that the modulation region should be much larger, between 50 and 150 AU. Further, Dorman [5] took into account the drift effects (as depending upon the sign of solar polar magnetic field) and showed different effects for even and odd solar cycles (see also [6]). However, some of the recent studies of time lag and hysteresis effect (e.g. [6-15]) have suggested interesting interpretation (in terms of drift/diffusion effects), implications and consequences (for modulation models) of the observed differences in time lags as well as differences in shapes, sizes etc. of the hysteresis loops during odd and even cycles.

In this work we have used various solar, geomagnetic and interplanetary parameters against CRI (Climax NM) to calculate the time lag between them. We found different lags in different conditions of solar activity and solar polarity. In the light of these results, we have tried to explain some interesting facts about the interplanetary space.

II. Results

In Figure 1, we have shown lags between various parameters and CRI. First column's panels are drawn for different solar polarity epochs while of second column are for low solar activity periods (combining the periods 1973-77, 1983-87, 1997-97, and 2003-08) and high solar activity periods (combining the periods 1968-72, 1978-82, 1988-92, and 1998-2002). From this figure we observe that there is a larger lag between SSN and CRI during A<0 period than A>0 but opposite is the case for the lag between TA and CRI (see also [12],[15]). Also, there is no lag observed in between B (and aa) and CRI in any of the polarity epoch.

As shown in the second column of the Figure 1, we find that there is no lag in between B (and aa) and CRI, neither in high activity periods nor in low activity periods. Also, there is no lag between SSN (and TA) against CRI for low activity periods. However, for high activity periods, there is a lag of 5 months between SSN and CRI and of 9 Carrington rotations between TA and CRI. These results are summarized in Tables I and II.

III. Conclusions

We study the time lag between solar (SSN), interplanetary (B), geomagnetic (aa) and heliospheric (TA) parameters against cosmic ray intensity. We observe that on an average, the time lag of CRI with solar activity is smaller (6 months) during A>0 than A<0 periods (10 months). On the other hand, it is larger (12 Carrington rotations) with TA during A>0 as against A<0 when lag is only 1 Carrington rotation. During low activity periods there is no lag with SSN while it is about 5 months during high activity periods on the average.

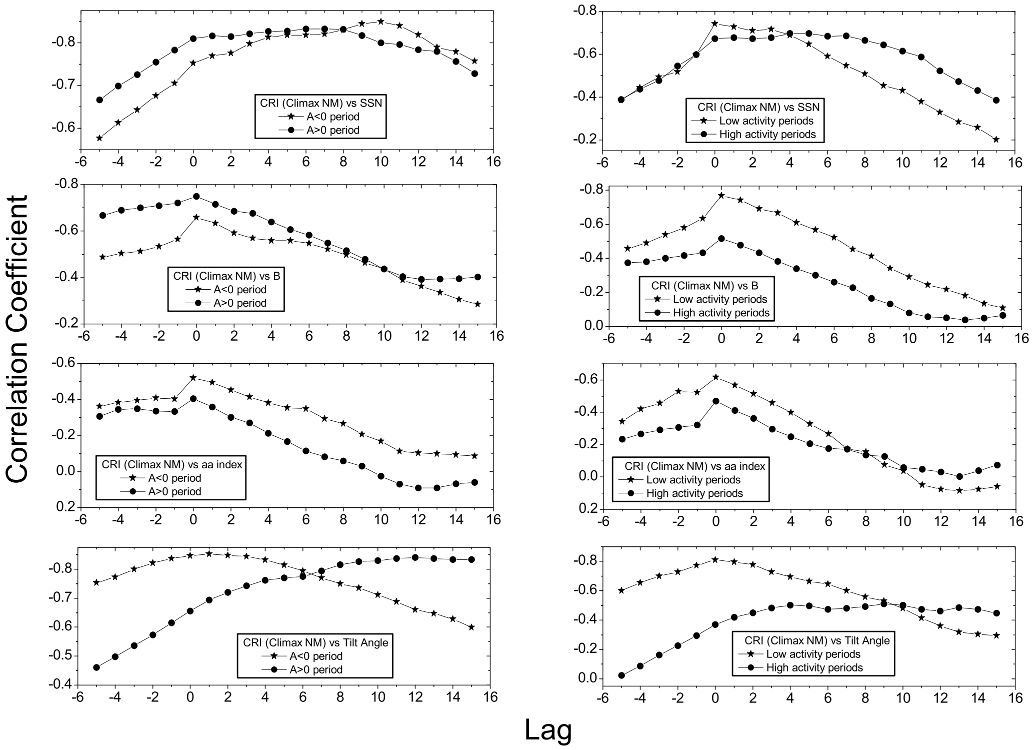

Fig. 1: Time lag and correlation between CRI and SSN, aa, B for 23 months and between CRI and TA for 23 Carrington rotations .

TABLE I: Time lag and (maximum) correlation coefficient between CRI and solar/interplanetary parameters during A<0 and A>0 polarity.

Polarity	SSN		TA		aa		B	
	lag	r	lag	r	lag	r	lag	r
A<0	10	-0.85	01	-0.85	00	-0.52	00	-0.66
A>0	06	-0.83	12	-0.84	00	-0.41	00	-0.75

TABLE II: Time lag and (maximum) correlation coefficient between CRI and solar/interplanetary parameters during low and high solar activity periods.

Polarity	SSN		TA		aa		B	
	lag	r	lag	r	lag	r	lag	r
Low activity	00	-0.74	00	-0.81	00	-0.62	00	-0.77
High activity	05	-0.70	09	-0.58	00	-0.47	00	-0.52

REFERENCES

[1] A.V. Belov, R.T. Gushchina, V.N. Obridko, B.D. Shelting, and V.G. Yanke (2006), *J. Atmos. Sol. Terr. Phys.*, 68 (11), 1161.

[2] L.I. Dorman (1957), *Cosmic Ray Variations*, Gostekhteorizdat, Moskow.

[3] H.V. Neher and H.R. Anderson (1962), *J. Geophys. Res.*, 67, 1309.

[4] L.I. Dorman (1975), *Variations of Galactic Cosmic Rays*, Moscow University Press, Moscow.

[5] L.I. Dorman (2001), *Adv. Space Res.*, 27 (3), 601.

[6] R.P. Kane (2003), *J. Geophys. Res.*, 108, 1379.

[7] H. Mavromichalaki, A. Belehaki, and X. Rafios (1998), *Astron. Astrophys.*, 330, 764.

[8] J.A. Van Allen (2000), *Geophys. Res. Lett.*, 27, 2453.

[9] I.G. Usoskin, K. Marsula, H. Kananen, and G.A. Kovaltsov (2001), *Adv. Space Res.*, 27, 571.

[10] E.W. Cliver, and A.G. Ling (2001), *Astrophys. J.*, 551, L189.

[11] A. Ozguc, and T. Atac (2003), *New Astronomy*, 8, 745.

[12] M. Singh, Y.P. Singh, and Badruddin (2008), *J. Atmos. Sol. Terr. Phys.*, 70, 169.

[13] I. Sabbah, and M. Rybansky (2006), *J. Geophys. Res.*, 111, A01105.

[14] A.P. Mishra, M. Gupta, and V.K. Mishra (2006), *Solar Phys.*, 239, 475.

[15] Badruddin, M. Singh, and Y.P. Singh (2007), *Astron. Astrophys.*, 466, 697.