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Hysteresis effect of the cosmic ray intensity of 10 GV

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Abstract: In this work the hysteresis effect of the cosmic ray intensity with rigidity of 10 GV at the top of the atmosphere which are obtained from all ground- based neutron monitors of the worldwide network in comparison to the sunspot number and the solar flux of 10.7 cm have been studied, during the solar cycles 20- 23. The anticorrelation between the cosmic ray variations of 10 GV and the above solar indices as well as the hysteresis effect, are obvious. Our results are in very good agreement with those obtained from previous works on individual neutron monitor stations. It is also confirmed that the time lag of the cosmic ray intensity of 10 GV against the two solar indices presents a different behavior between even and odd solar cycles due to the polarity reversal of the solar magnetic field. Finally, it is concluded that the time series of cosmic rays of 10 GV is in response to the neutron monitor data and is very useful for the cosmic ray modulation and space weather studies.

1 Introduction

The galactic cosmic-ray intensity presents a nearly 11-year variation anticorrelated with the solar activity, with some time lag. Many researchers have investigated this long term variation of the cosmic-ray intensity through means of different solar indices and geophysical parameters [1],[2]. In this work, the effect of the hysteresis in the relationship between the cosmic rays of 10 GV and the two solar indices, sunspot number and solar flux of 10.7 cm, were studied for the entire time period of 1964-2007 and separately for each solar cycle 20, 21, 22 and 23 covering this period. Results of this study are comparing with the corresponding ones using data from two separate neutron monitors of Moscow and Oulu stations [3]. Cosmic rays of 10 GV are obtained from all ground based neutron monitor stations located in different places of the world and not from a single detector. As it is independent from the cut-off rigidity phenomena, these data are more efficient in order to show more representative results.

2 Data and Method

Monthly values of cosmic ray intensity of 10 GV at the top of the atmosphere obtained from the worldwide network of neutron monitors (www.nmdb.eu) using the global survey method[4],were used.This method uses data from as many ground-based detectors as possible and provides useful and reliable information on the conditions of the space environment. Monthly values of the sunspot number Rz and the solar flux of 10.7 cm were also used obtained from the National Geophysical Data Center (ftp://ftp.ngdc.noaa.gov/STP/space-weather/solar-data) and Geological Survey of Canada (ftp://ftp. Geolab .nrcan.gc.ca), respectively. The time lag of these two parameters with their statistical errors in reference to the cosmic-ray intensity of 10 GV was calculated from the cross-correlation coefficients between them with varying time lags from 0 to 30 months. This analysis was performed for each cycle separately and for the total interval of 1964-2007. The best correlation coefficient in each case gives the time lag of the cosmic ray intensity with each one examined parameter [5].To confirm the results, the hysteresis curves between the cosmic-ray intensity of 10 GV and each one of the parameters were designed (Figure 1).

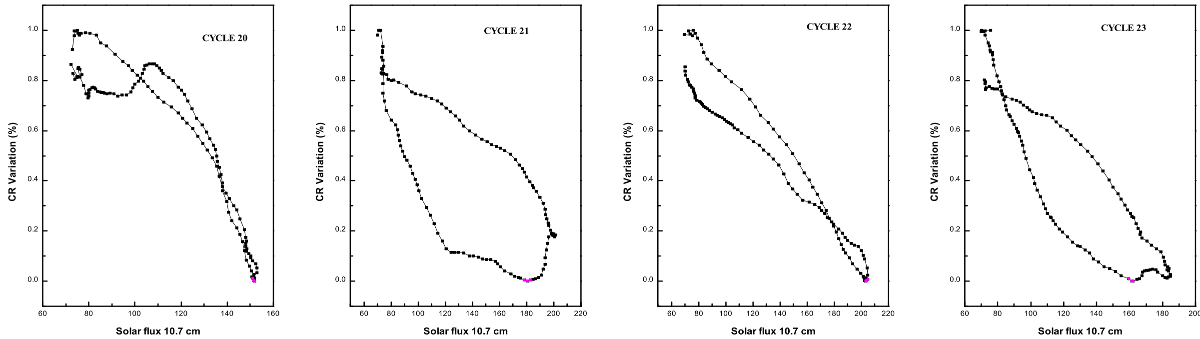

Figure 1: Hysteresis curves of the cosmic-ray intensity of 10 GV with respect to the solar flux 10.7 cm (F10.7) for cycles 20, 21, 22 and 23.

3 Results and Conclusions

- A comparative study of the long-term modulation of the cosmic ray data of 10 GV equivalent to the cosmic ray intensity as it is recorded in the Earths orbit at 1 AU, with a previous work [3] using data from two single detectors (Moscow and Oulu), was attempted.
- By applying a similar correlative analysis, results are in very good agreement with those obtained on individual neutron monitor stations.
- A distinct difference between odd and even solar cycles is obvious. For odd cycles the time lag reached large values in contrast to the even ones (Tables 1 and 2).
- We also remarked that the correlation coefficients between the cosmic-ray intensity and the two solar parameters are satisfactory [5].
- The studies on these issues will be useful in solar cycle prediction and space weather applications.

Table 1			Neutron Monitor Stations			
	CR 10 GV		Moscow NM		Oulu NM	
Solar Cycles	Cor. Coef. (r) (95% SL)	Time lags (m)	Cor. Coef. (r) (95% SL)	Time lags (m)	Cor. Coef. (r) (95% SL)	Time lags (m)
20	**-0.79±0.01**	**1**	**-0.83± 0.01**	**2**	**-0.87± 0.01**	**1**
21	**-0.81±0.01**	**11**	**-0.86± 0.01**	**16**	**-0.85± 0.01**	**11**
22	**-0.89±0.01**	**4**	**-0.91± 0.01**	**4**	**-0.91± 0.01**	**4**
23	**-0.84±0.01**	**13**	**-0.84± 0.01**	**13**	**-0.85 ± 0.01**	**13**
Total	**-0.83±0.01**	**7**	**-0.86± 0.01**	**9**	**-0.87± 0.01**	**7**

Table 2			Neutron Monitor Stations			
	CR 10 GV		Moscow NM		Oulu NM	
Solar Cycles	Cor. Coef. (r) (95% SL)	Time lags (m)	Cor. Coef. (r) (95% SL)	Time lags (m)	Cor. Coef. (r) (95% SL)	Time lags (m)
20	**-0.78±0.01**	**1**	**-0.82± 0.01**	**2**	**-0.87± 0.01**	**1**
21	**-0.84±0.01**	**11**	**-0.88± 0.01**	**16**	**-0.87± 0.01**	**11**
22	**-0.89±0.01**	**3**	**-0.92± 0.01**	**3**	**-0.92± 0.01**	**1**
23	**-0.83±0.01**	**13**	**-0.83± 0.01**	**13**	**-0.85 ± 0.01**	**13**
Total	**-0.84±0.01**	**7**	**-0.86± 0.01**	**9**	**-0.88± 0.01**	**7**

Table 1 (Left):Correlation coefficients with their errors and time lags in months of CR and Rz. **Table 2** (Right): The corresponding ones for CR and radio flux 10.7cm.

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