Variation of Cosmic Ray Intensity with Angular Distance from Earth to the Current Sheet

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Abstract

We have studied the cosmic ray intensity variations, during different polarity states of the heliosphere, with day-to-day changes in the angular distance from the earth to the current sheet. The results show intensity maxima at heliosphere current sheet (sector crossing) and minima away from the current sheet during both the periods of positive solar magnetic polarity ($A > 0$) and negative magnetic polarity ($A < 0$). Differences in cosmic ray intensity gradient away from the current sheet, during two polarity conditions of the heliosphere ($A > 0$ and $A < 0$), have also been observed. The amplitude of variation, due to azimuthal gradients, is larger for $A > 0$. This result is in agreement with the 3-dimensional model calculations including large scale particle drifts in the heliosphere with a wavy current sheet. We have calculated the gradients during both the polarity states of the heliosphere by adopting a simple procedure. This quantitative estimate is expected to be of interest, in particular to those involved in 3-dimensional modeling of galactic cosmic rays in the heliosphere.

1. Introduction

The study of effects of HCS crossing (sector boundary) upon the cosmic ray intensity has shown [1-3, 7-9] that the intensity is highest at the HCS crossing and decreases away from the HCS for both polarities $A > 0$ and $A < 0$, and the magnitude of decreas is larger for $A > 0$. Recent model calculations [5] predictions are in agreement, atleast qualitatively, with these results. Recently, study of the recurrent modulation [10] has shown that modulations are larger during $A > 0$ epochs. Again, the recent simulation results [6] are consistent with experimental results [10] if HCS happens to be placed asymmetrically. Although cosmic ray data analyses results were suggestive of asymmetric displacement of HCS [2,11,14], it has been confirmed only recently [12,13]. In this work, we estimate intensity gradients, compare with recent 3-D modulation results and look for evidence, if any, for the possibility of asymmetrically placed HCS.

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2. Methods

Angular distance from earth to the current sheet (λ) and neutron monitor intensity (%) have been subjected to superposed epoch analysis during the periods of different condition of large-scale heliospheric magnetic field ($A > 0$ and $A < 0$). Epoch days correspond to the days of polarity reversal (sector crossing) from positive to negative and vice versa. Only those days have been considered as epochs when the polarity did not change for at least five days before and after the reversal. Moreover, we have restricted to only those days as epochs when the sector crossing was also observed on the day of polarity change or within ± 1 day of the change.

3. Results

In Fig. 1, we have plotted the angular distance from earth to the current sheet λ (deg) and cosmic ray intensity (%) during the years and periods of different magnetic conditions ($A > 0$ and $A < 0$). It is seen that cosmic ray intensity in general decreases in both the sectors, positive and negative (above and below the HCS), as the distance from earth to the current sheet increases. The gradient is larger for $A > 0$ epoch. Least Square fit estimate provides cosmic ray gradient of -0.044% per degree in $A > 0$ as compared to -0.024% per degree in $A < 0$ magnetc conditions. Moreover, there is a difference in gradient in positive and negative sectors during the same epoch ($A > 0$ or $A < 0$).

4. Discussion

Calculated gradients at the earth, obtained for 5 GeV galactic cosmic rays in the 3-dimensional simulation with a wavy HCS [5], predict that the total decrease (in %) in the intensity away from the HCS is twice as large in $A > 0$ state than $A < 0$ polarity state. Recurrent near-earth variations are found to be $\sim 50\%$ larger during $A > 0$ epoch than during $A < 0$ epoch [10]. Present study estimate provides a cosmic ray density gradient of -0.044 % per degree in $A > 0$ as compared to -0.024 % per degree in $A < 0$ magnetic conditions. A detailed superposed epoch analysis of the cosmic ray neutron monitor data with respect to sector boundaries (HCS crossings) during different solar and magnetic conditions led us [1] to suggest the possibility of displaced (asymmetrically placed) HCS. Apart from the cause(s) of the HCS displacement (e.g. see [12, 13]), galactic cosmic ray [11] and anomalous cosmic ray [14] observation of north-south asymmetry and asymmetry in 'source surface neutral line' as well confirmed the offset of HCS. Findings [10] that the magnitude of 26-day recurrent variations are larger in amplitude for $A > 0$ are in qualitative agreement with simulation results [6] after considering that the HCS happens to be placed asymmetrically. Results

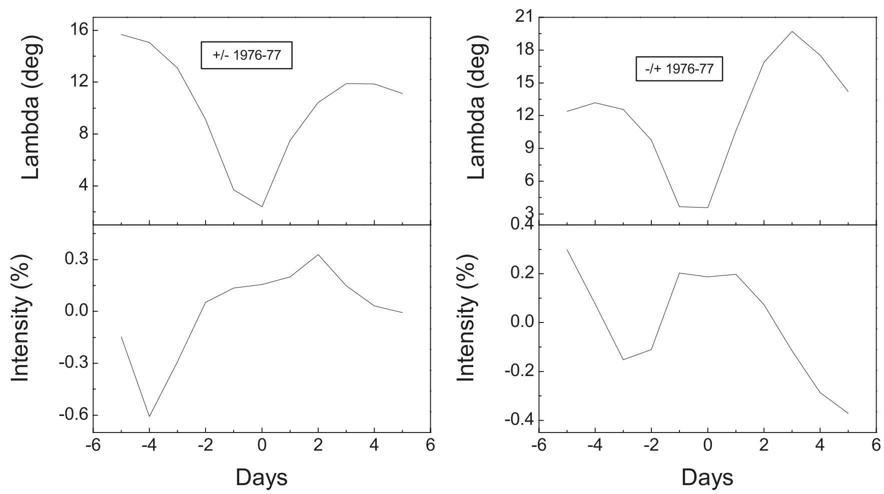

Fig. 1. Superposed results showing variation of angular distance from earth to the current sheet (degrees), neutron monitor intensity (%) with respect to HCS crossing during $A > 0$.

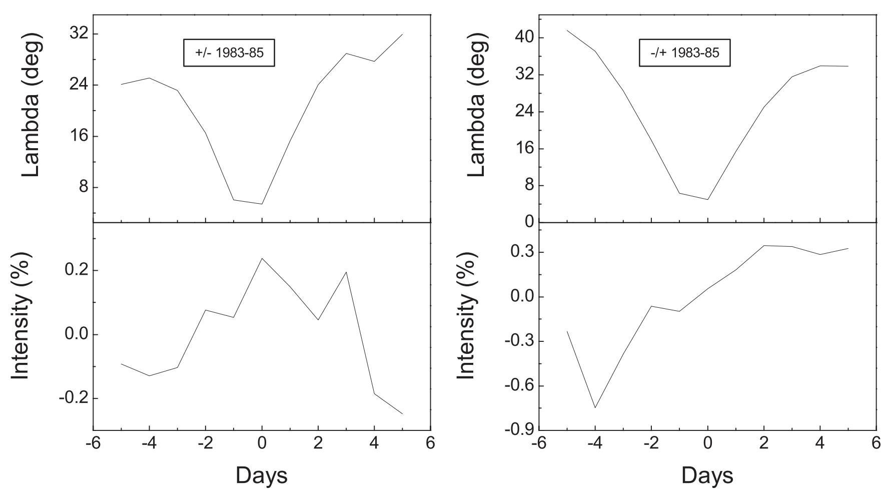

Fig. 2. Superposed results showing variation of angular distance from earth to the current sheet (degrees), neutron monitor intensity (%) with respect to HCS crossing during $A < 0$.

presented in this paper, in addition to being in agreement with the simulations, are also suggestive to asymmetric displacement of HCS as the extent of earth excursion in heliomagnetic latitude appears to be somewhat different above and below the HCS.

5. Conclusions

Cosmic ray intensity is maximum at the time of passage of heliospheric current sheet. It decreases as the distance from earth to the current sheet increases during both the magnetic conditions $A < 0$ and $A > 0$. Further, cosmic ray intensity is more strongly affected during $A > 0$. Estimated gradient with respect to HCS is larger during $A > 0$ than $A < 0$. These results are in agreement with the recent three-dimensional model calculations of [6]. The difference in gradient when the earth is in positive sector as compared to the situation when it is in negative sector, in the same epoch, is possibly due to asymmetric displacement (offset) of the HCS.

6. References

1. Badruddin, Yadav, R.S., Yadav, N.R. 1985, Planet Space Sci. 33, 191
2. Christon, S.P. et al. 1986, JGR 91, 2867
3. El-Borie, M.A., Duldig, M.L., Humble, J.E. 1997, Proc. 25^{th} ICRC, Durban 2, 113
4. Kota, J. and Jokipii, J.R. 1982, GRL 9,656
5. Kota, J. 2001, Proc. ICRC 2001, Hamburg, 3939
6. Kota, J. and Jokipii, J.R. 2001, Proc ICRC, Hamburg, 3577
7. Newkirk G. and Lockwood, J.A. 1981, GRL 8, 619
8. Newkirk, G. and Fisk, L.A. 1985, JGR 90, 3391
9. Otaola, J.A., Valdes-Galicia, J.F. and Moussas, X. 1989, Ann. Geophys, 7(2), 161
10. Richardson I.G., Cane, H.V., Wibberenz, G. 1999, JGR, 104, 12549
11. Simpson, J.A. et al. 1996, ApJ 465, L69
12. Smith, E.J. et al. 2000, ApJ 553, 1084
13. Smith, E.J. 2001 JGR 106, 15819
14. Tattner K.J. et al. 1997, GRL 24, 1719