Galactic Cosmic Ray and Recurrent Enhancement of Solar Wind Velocity

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Abstract

Long-term variations of the intensity for galactic cosmic rays and low energy ions have been investigated using the solar wind parameters. A distinct long-term decrease of cosmic rays intensity associated with the recurrent corotating interaction regions was observed at 1AU in 1993/94. The recurrent enhancements of solar wind velocity and low energy ion intensity were observed in this period. In particularly, it was found that the peak solar wind velocity have good anti-correlation with the high energy galactic cosmic ray intensity. In this event, recurrent enhancements of solar wind velocity are closely associated with the long-term decrease in the galactic cosmic ray intensities.

1 Introduction:

The temporal variation of Galactic Cosmic Ray (GCR) intensity is affected by solar phenomena like solar flares, Coronal Mass Ejections (CME) and other high-speed streams. The short-term variation of GCR intensity at 1 AU with a time scale of days is closely related to the passage of interplanetary shocks, for example, driven by CMEs or the formation of corotating interaction regions (CIRs) [Hasebe et al., 1995]. Long- lasting decreases in the GCR intensity often observed at 1AU are related to the passage of a series of transient shock-associated flows [Burlaga et al., 1993]. In this paper, the long-term decrease in the GCR intensity with a time scale of 0.5 - 1 year are studied in the period in 1993/94.

It is considered that large and long-term decreases in the GCR intensity are associated with the merged interaction regions (MIRs) [McDonald et al., 1981]. MIRs are spatially large regions with intense magnetic fields formed by the nonlinear interaction and the coalescence of distinct interaction regions, shocks, and ejecta. There is a growing evidence that long-term decreases in the GCR intensity over half a year are caused by MIRs. The MIRs were classified into three types by Burlaga et al. [1993]: "global MIRs" (GMIRs), "corotating MIRs" (CMIRs), and "local MIRs" (LMIRs). GMIRs are mainly associated with large transient events such as large solar flares and CMEs. In the maximum phase of solar activity, GMIRs sometimes cause the long-term decrease in the GCR intensity [Burlaga et al., 1993]. CMIRs are produced by the merging of recurrent CIRs that eventually coalesce in the outer heliosphere as they propagate outward from the sun. It is not thought that CMIRs cause long-term decreases in the GCR intensity because the net variation of GCR intensity does not decrease.

In this paper, we have examined the relation between the intensity decrease of GCRs and recurrent CIRs using He (4-10MeV/n) data from the GEOTAIL satellite and solar wind velocity data from the IMP-8 satellite.

2 Observation:

CIR event is characterized by enhanced plasma densities and magnetic field intensity combined with compressional plasma heating. The CIR includes the stream interface characterized by enhancements in the solar wind speed and plasma temperature, a decrease in plasma density, and a change in the flow angle relative to the radial direction. We have identified the CIR events by the stream interfaces using plasma data from IMP-8 satellite.

Recurrent intensity increases of He ions (with 4 - 10MeV/n) were observed by the GEOTAIL satellite from Sep. 1993 to Sep. 1994 when solar activity was declining. The relationship between the increases of He ion intensity associated with CIRs and the short-term (in the order of days) decreases in the GCR intensity during the period from Dec. 1993 to Apr. 1994 were studied by Hasebe et al.. They have found that the variation of the counting rates of neutron monitors is well correlated with the flux variation of low energy ions. They have suggested that corotating streams cause the decrease of GCR flux because they act as barriers that impede the flow of GCRs toward the Sun. In this paper, the relationship between long-term decrease in GCR intensity, CIR events is investigated.

Figure 1 shows the time profile of the neutron monitor counting rate observed at Deep- River station, i.e. GCR intensity $>$ 1GV (top panel), the intensity of He ions with energies 4 to 10 MeV/n (second panel), and solar wind velocity observed at the IMP-8 satellite (bottom panel) during from 305 to 721 days since 1st Jan. 1993. The arrows in the middle panel show the solar events like solar flare and CME events. The meshed thick lines over three panels show the day when the interface of CIR passed at 1 AU identified using solar wind parameters. The long-term decrease in GCR intensity over half a year is seen in the top figure. This long-term decrease consists of a lot of short- term decreases. The large three continuous short-term decreases of them form the peak decrease of this long-term decrease. One of the short-term decreases was caused by a solar flare event, while the other two events were caused by CIR events. The intensity in most of short-term decreases recover to primary intensity. Only one event just before the large three decreases don't recover to primary intensity. A lot of enhancements in the low energy He ion intensity were observed in the period of this long-term decrease event. The large recurrent distinct enhancements in that intensity are seen since before the peak decrease term in middle panel.

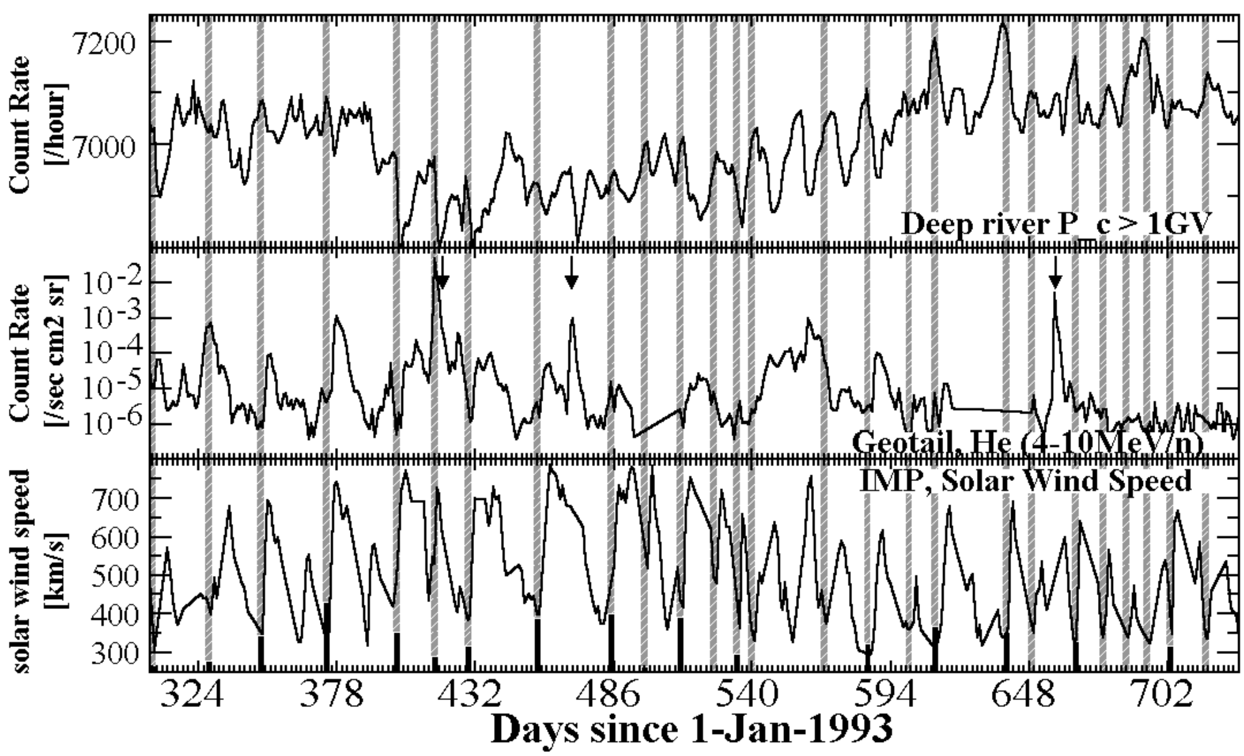

Figure 1: Time profile of the neutrom monitor count rate (top panel), intensity in low energy He ions (middle panel), and velocity of solar wind (bottom panel) at 1AU during from 305 to 721 days since 1st. Jan. 1993.

We have selected and shown the variations of solar wind velocity among the some plasma parameters in this figure because the long-term decreases in the GCR intensity have a better correlation with solar wind velocity than magnetic field strength, plasma density, and the other plasma parameters. High-speed corotating streams were recurrently observed over half a year. In usually, the solar wind velocity is about 300km/s. Most of the enhancements in solar wind velocity in bottom panel are over twice of the usual speed. In particularly, the significant enhancements are seen during the period when the long-term decrease in GCR intensity was observed. The thick line in bottom panel shows the range of solar wind speed between low and high speed in each CIR events. Some of the range of solar wind speed are over 400 km/s, but the no characteristic enhancements are seen only in the long-term decrease period.

The peak speeds of solar wind and recovered count rates of GCR intensity are picked up in order to investigate the relationship between the long-term decrease in GCR intensity and recurrent enhancement of solar wind velocities. Figure 2 shows the time profile of peak speed of solar wind and recovered GCR intensity during from 305 to 737 days since 1st, Jan., 1993. The GCR intensity was subtracted from 8000 counts for easy to see. The curved lines in the fig. 2 shows the fitted lines by four-order polynomial expression. The two lines have a very similar time profile. This long-term decrease have little delay time from the high speed solar wind events. If this long-term decrease were caused by CMIRs, they should have some delay time.

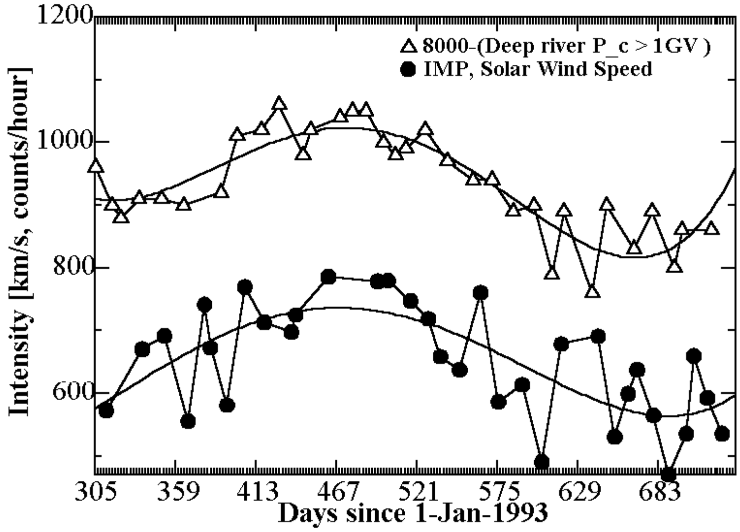

Figure 2: Time profile of peak speed of solar wind and recovered GCR intensity during from 305 to 737 days since 1st, Jan., 1993. The GCR intensity was subtracted from 8000 counts

3 Summery and Discussion:

We have examined the relationship between the long-term decrease of 0.5-1 year in the galactic cosmic ray intensities and recurrent corotating interaction region events in 1993/94. The peak solar wind speed had a good anti-correlation with the galactic cosmic ray intensity at the time when it was recovered, and they have only very small delay time. If CMIRs caused this long- term decrease in galactic cosmic ray intensity, they should have larger delay time. From other observation in past [Burlaga et al. 1984], however, it is said that CMIR cannot cause the long- term decrease. The recurrent enhancements in low energy ion intensiy are seen near this long- term decrease event, they are particularly seen around the peak decrease period. This may imply that the CIRs cause this long-term decrease. However, the range of solar wind velocity have not so obvious characterictics associated with the time-variation of galactic cosmic ray intensity. In this time, we can say only that this long-term decrease in galactic cosmic ray intensity in 1993/94 were closely associated with the recurrent large enhancements of solar wind velocity.

References

Burlaga, L. F., F. B. McDonald, N. F. Ness, R. Schwenn, A. J. Lazarus, and F. Mariani, Interplanetary flow systems associated with cosmic ray modulation in 1977-1980, J. Geophys. Res., 89, 6579, 1984.

Burlaga, L. F., F. B. McDonald, and N. F. Ness, Cosmic ray modulation and the distant heliospheric magnetic field: Voyager 1 and 2 observations from 1986 to1989, J. Geophys. Res., 98, 1, 1993.

Hasebe, N., K. Kondoh, M. Kobayashi, Y. Mishima, T. Doke, B. Wilken, et al., Corotating ion events associated with cosmic ray modulation, J. Geomag. Geoelectr., 47, 1333, 1995.