Magnetospheric transmissivity for cosmic rays during selected recent events with interplanetary/geomagnetic disturbances

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ABSTRACT

Variability of CR (FD) observed at selected european NMs around the moderate geomagnetic disturbances, namely during intervals (a) DOY 316-321 in 2012, (b) DOY 274-276 in 2013, (c) DOY 49-51 in 2014 and (d) DOY 58-59 in 2014 is discussed. Assuming the primary spectra by CREME96 model, yield function and geomagnetic transmissivity changes in Tsyganenko96 model, the expected increases at middle latitude station Lomnicky stit, are compared with the observed ones. The examples stress the importance of including anisotropy of CR flux in interplanetary space, other geomagnetic field models and yield functions to the computations.

Keywords: cosmic ray variations, FD, geomagnetic cut-off rigidity, Tsyganenko models

1 Introduction

Recent period is characteristic by not many irregular changes in CR intensity observed by NMs. Four events with different behaviour in CR measured by selected european NMs (data from PIs and/or from http://nmdb.eu) during Dst depressions are used to illustrate the variety of increases/decreases at NM around the times when IMF B and solar wind interacted with magnetosphere.

2 Description of events

Fig.1. Four intervals with variations of CR records at selected european NMs with different geomagnetic cut-offs when Dst in minimum was < -60 nT. Normalization in CR is done to unity for average of first 12 hour interval of the hourly count rate at each station. Along with Dst (Kyoto) the hourly values of solar wind pressure (p), solar wind density and velocity (NSW, VSW) and magnitude of IMF B as well as its latitude in GMS system is plotted (data downloaded from http://omniweb.gsfc.nasa.gov NASA site).

3 Discussion and geomagnetic transmissivity

At the minimum of Dst the event ***a*** shows stronger increase in CR probably due to improvement of magnetospheric transmissivity at LS, JJ1 and Rome (middle cut-offs rigidities) than at Oulu. At Oulu the decrease of geomagnetic cut-off is not producing a strong increase in CR, since it is close to the atmospheric cut-off.

In the event ***b*** the decrease is „organized" according to nominal geomagnetic cut-off rigidities, deepest at Oulu, smallest at Rome. This event can be studied in more details for the rigidity dependence of FDs with larger number of NMs, similarly as it was done in more details for many FDs e.g. in papers (*Alania and Wawrzynczak, 2012; Alania et al., 2013*).

The event ***c*** is a candidate for checking validity of geomagnetic field models with external current sources, since the increase is most probably due to the change of magnetospheric transmissivity at middle latitude NMs.

Event ***d*** is also showing different behavior of CR records at Oulu with respect to the middle latitude stations (JJ1, LS, Rome), also a candidate for checking magnetospheric transmissivity change according to different models.

Let us assume what may be expected increase in NM count rate due to decrease of geomagnetic cut-off. Figure 2 shows the approach.

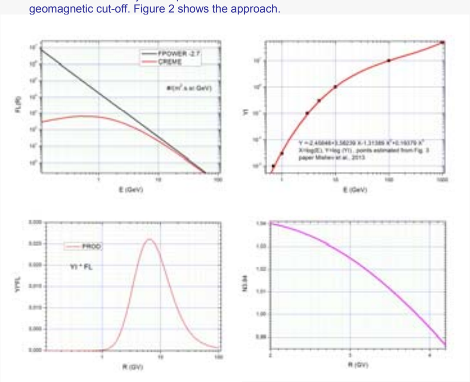

*Fig.2. **a.** differential flux of **p** from CREME 96 (solar max) and spectra from (RPP12, par. 26) . **b .** approximated yield function from Fig.3 in paper (Mishev et al, 2013). **c.** product of differential spectra (Tylka et al, 1997, CREME96) and the yield function. **d.** integral of the function plotted in c (integration above the given rigidity R, normalized to unity for Lomnicky stit position with geomagnetic vertical nominal cut-off 3.84 GV).*

In simplified assumptions (neglecting anisotropy, using yield function at sea level) we tried to estimate the effect of change of count rate for one model Ts-96. Vertical geomagnetic cut-off rigidities have been computed by the tool available at http://www.geomagsphere.org/geomag/ (*Bobik et al., 2006*). Figure 3 illustrates comparison of improved transmissivity according to the model with the increase of count rate at LS for two events.

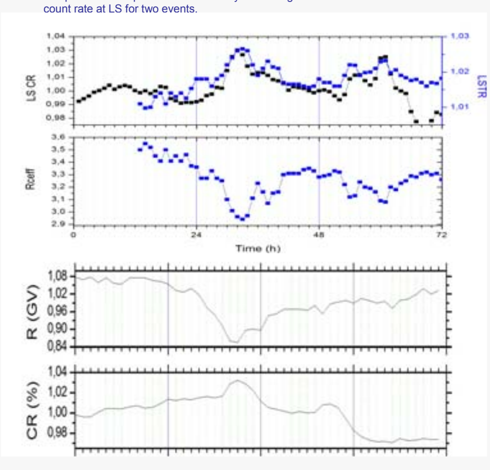

Figure 3.

Fig. 1a

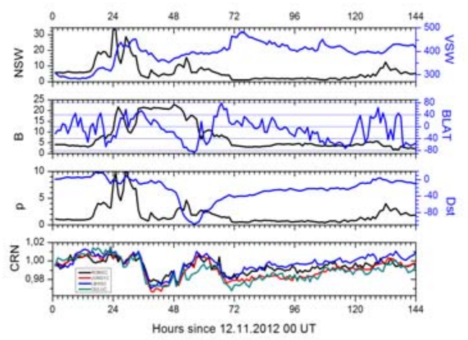

Fig. 1b

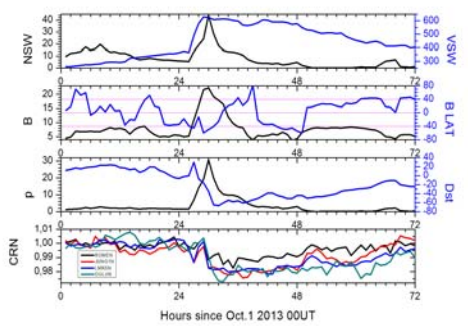

Fig. 1c

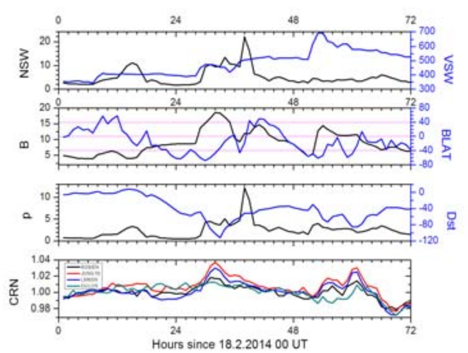

Fig. 1d

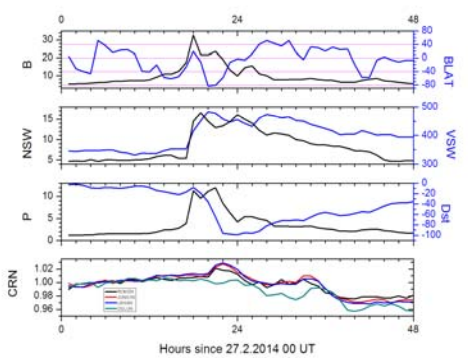

Fig. 3. **a.** upper: for event ***c*** the effective cut-off rigidity Rceff and using results in Fig. 2 leads to comparison of measured (LSCR) and expected (LSTR) normalized count rate at Lomnicky stit. **b.** for event ***d*** the blue arrow corresponds to Rceff = 3.26 GV and increase in CR is 1.03 with respect to 1200 UT on the same day when Rceff = 4.03 GV and CR was at level 1.01.

In the event ***c*** the profile (at least in times of increases when Dst is near local minima) measured by NM LS corresponds qualitatively to the expected (LSTR) one based on Ts-96 model and the yield function used. However the increases are about factor ~ 2 – 3 larger than those expected only by simple assumptions and exclusively by transmissivity changes of magnetosphere.

For the event ***d*** at 2200 UT on Feb. 27, 2014 the value obtained from Fig. 2d is expected 1.0182 and for 1200 the value estimated is 0.993, the difference is ~2.5% which is consistent with the measurement (even slightly higher than observed).

There are several studies of changes of cutoffs during geomagnetic and interplanetary disturbances (*e.g. Tyasto et al, 2004; Kudela et al., 2008*). Review of geomagnetic models for CR trajectory computations is e.g. in paper (*Smart et al, 2000*) or in monograph (*Dorman, 2009*). The approach used here is very simplified: there is no anisotropy (yet) in interplanetary space assumed, only vertical direction of acceptance of particles from above the NM position, yield function used is computed for the sea level and just one geomagnetic field model with external current sources is used. The difference in using two models for cut-off rifidity is illustrated in Fig.4 .

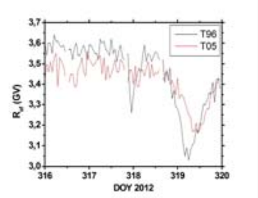

Fig. 4. Effective vertical cut-offs computed for two models in event ***b***. While minimum Rceff = 3.05 GV for Ts96, for T05 Rceff = 3.18 GV and times of minima is different.

4 Concluding remarks

Relatively nonfrequent and not very strong decreases in CR (FD) have been observed in the past two years. The events, however, can be studied using data bases as http://nmdb.eu , *Watanabe,2013* http://center.stelab.nagoya-u.ac.jp/WDCCR and others to check in detail the variability of CR, especially increases due to geomagnetic transmissivity changes for individual intervals with disturbances in the magnetosphere.

Parameters of GCR as density and anisotropy can be derived from the data of the world wide NM network by Global Survey method (*Asipenka et al, 2011*). Problems are rather complex, and this has to be done jointly with analysis of interplanetary plasma/IMF structures as CMEs, ICMEs, magnetic clouds, interplanetary shocks producing variety of anisotropies. It is not easy to ***deconvolute the anisotropy in interplanetary medium from geomagnetic field reconfiguration***, since they appear very often simultaneously. Anisotropy can be obtained from combination of (1) Spaceship Earth measurements (*Bieber and Evenson, 1995*) covering low energy CR flux and being practically independent on magnetospheric changes, and on the other hand from (2) GMDN (*Munakata et al, 2000*) and other new muon detectors which provide anisotropy at higher energies of primaries than those at NMs and for them also both geomagnetic cut-offs as well as asymptotic directions are only slightly dependent on the magnetospheric state. In several cases the variability at NMs is not only „organized" by geomagnetic cut-off (in addition to anisotropy and connected asymptotic directions), but also records of high mountain detector variations due to magnetospheric screening are different from those at sea levels. Variability of CR is in some studies presented also as a function of median rigidity which includes the altitude of the station (*e.g. Ahluwalia and Ygbuhay, 2013*).The yield functions computations obtained from simulations for high altitudes can be checked by the NM measurements during the isolated geomagnetic disturbances when reasonable assumptions on anisotropy can be included.

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