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ANNUAL AND SEMI ANNUAL VARIATIONS OF THE GALACTIC COSMIC RAY INTENSITY AND SEASONAL DISTRIBUTION OF THE CLOUDLESS DAYS AND CLOUDLESS NIGHTS IN ABASTUMANI (41.75N, 42.82E; GEORGIA): (1) EXPERIMENTAL STUDY AND (2) THEORETICAL MODELING

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PROBLEM

A relationship of changes of the cloudless days (CD) and cloudless nights (CN) numbers with the GCR intensity variations is studied at first time based on the unique observational data in the Abastumani Astrophysical Observatory (Georgia) during 1957-1993. So, at the beginning we consider the behavior of the average GCR intensity in yearly period based on neutron monitors data. Then we compare results with similar changes of CD and CN for the same period. The inter-annual changes of atmospheric processes, including cloud covering in the lower atmosphere, can possibly be related to the seasonal changes of absorption of solar electromagnetic radiation energy by the Earth surface, which depend on geometry of solar-terrestrial position in the heliosphere. During Earth rotation around the Sun, the interplanetary and geomagnetic field geometry and, as a result, the influence of the solar corpuscular radiation on the events on the magnetosphere [1] and also the magnetosphere-ionosphere-atmosphere coupling change [2]. To generate geomagnetic disturbances by solar wind, the interplanetary magnetic field (IMF) and geomagnetic field configuration are effective at equinox months (March/April and September/October) [1], where the z component of the IMF is directed southward. The large number of geomagnetic disturbances at equinoxes and small number around solstice months gives semi-annual variability of frequency of appearance of the phenomena characteristic for magnetosphere-ionosphere-atmosphere coupling processes [3]. Solar wind disturbances cause changes not only in geomagnetic field, but modulate GCR flux, as well. These in turn can cause variations of ions produced by GCR and hence the density of cloud condensation nuclei (CCN). Thus, there is a possible coupling between changes in GCR flux and cloud formation processes [4], [5]. High mean day-night temperature in the lower atmosphere and the Earth surface can be favorable for cloudless days and nights. When a difference between day- and night-time temperatures is comparatively large, then cloud formation conditions are favorable, including the influence of cosmic factors, like GCR. Seasonal peculiarities of temperature variations from day to night as well as with height for given region of the lower atmosphere also can change the annual and semi-annual effect of production of CCN by GCR, which in turn may result in different behavior of cloud formation during day and night. Increase of the CCN density produced by GCRs flux enhancement, where the water vapor is near saturation, should stimulate the cloud formation processes and grow the cloudiness [6]. Decrease of GCRs flux in similar conditions should be favorable for cloudless days and nights. In the lower atmosphere where the clouds mostly are formed, the temperature and humidity variations are different for day and night. Because of this, the processes initiating cloud formation by GCR may be different during day and night. Together with seasonal as well as day-night variations of atmospheric conditions, it is possible that the impact of cosmic factors on cloud covering change by day-night and seasons.

CONCLUSIONS

The inter-annual distribution of cloudless days and nights in Abastumani Astrophysical Observatory reveals both annual and semi-annual variations for various levels of geomagnetic disturbances. For the annual cycle, the number of cloudless days is the biggest in August, which may be expectable, since in this month the mean day-night surface temperature in the region is maximal. In geomagnetically disturbed conditions ($Ap \geq 7$), having semi-annual character, the increase of number of cloudless days at equinoxes possibly cause the shift of maximal number of cloudless nights from August to September. This phenomenon and the fact that number of cloudless nights are the biggest in September and for less geomagnetic disturbances ($Ap < 40$) shifts back to August, point to the influence of cosmic factors on cloud covering processes. The GCRs flux change is considered as one of the possible cosmic factors, which reveals annual variations for cloudless nights, with the greatest decrease in June, where, for magnetically disturbed conditions, the maximal frequency of cloudless nights is observed.

The GCRs flux observed by Oulu NM shows a presence of some annual and inter-annual variations. These inter-annual variations differ from its modeling results but gives its noticeable reduction in June and August, where the relative number of CN and the total number of CD are increasing, respectively. This result should be important for improving an assumed model for investigation of the observed properties of the inter-annual variations of the CD and CN distribution.

EXPERIMENTAL DATA

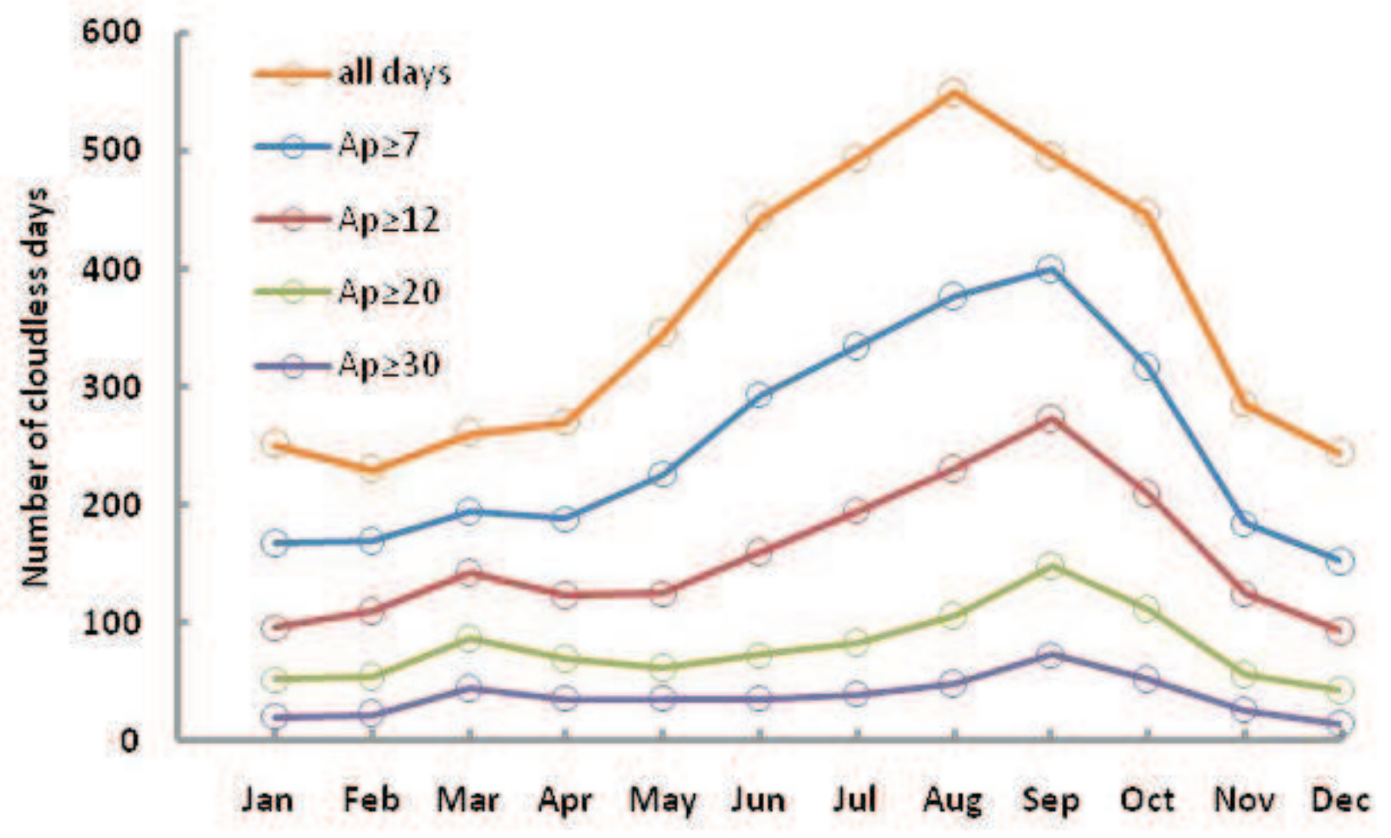

Fig.1. Inter-annual distribution of total monthly numbers of cloudless days in Abastumani Astrophysical Observatory in 1957-1993 at different geomagnetic disturbances: for $Ap \geq 7$ (blue), $Ap \geq 12$ (red), $Ap \geq 20$ (green) and $Ap \geq 30$ (violet). Yellow line corresponds to all cloudless days.

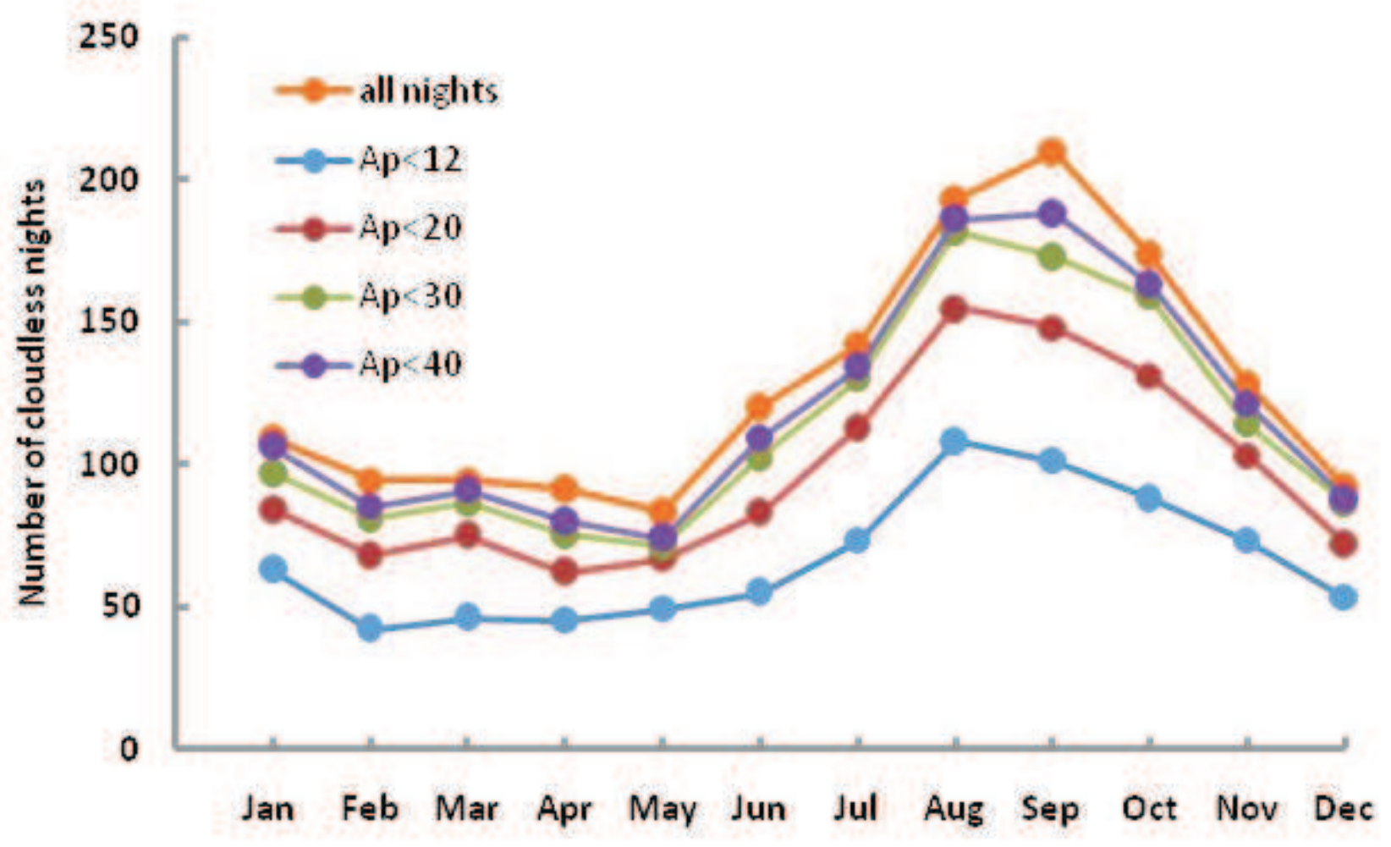

Fig.2. Inter-annual distribution of total monthly numbers of cloudless nights in Abastumani Astrophysical Observatory in 1957-1993 at different geomagnetic disturbances: for $Ap < 12$ (blue), $Ap < 20$ (red), $Ap < 30$ (green) and $Ap < 40$ (violet). Yellow line corresponds to all cloudless nights.

Fig. 1 shows that the biggest number of cloudless days is in August and during magnetically relatively disturbed conditions ($Ap \geq 7$) it shifts to September, where there is a maximal number of magnetically disturbed day-nights [1]. The increase of number of magnetically disturbed cloudless days is observed, both in September and March, pointing to semi-annual variations modulating the annual variations of cloudless days, which indicates the influence of cosmic factors on cloud covering. This phenomenon is enforced by the fact that maximal number of cloudless nights is in September (Fig.2) and at geomagnetically comparatively quiet periods ($Ap < 40$) is again in August, like for cloudless days.

We note that in this region the maximal day-night temperature at the surface is mostly observed in August and, as was mentioned, the number of cloudless day-nights is more expectable. During magnetically disturbed conditions, such annual distribution is modulated by semi-annual variations which can be caused by the influence of cosmic factors on the cloud covering. We assume that one of the cosmic factors, influencing on cloud covering processes, can be considered the inter-annual variations of GCRs flux at cloudless days and nights.

MODEL OF THE GCR INTENSITY VARIATION

We model the variation of the GCR using the Parker's time-dependent transport equation [7]:

$$\frac{\partial N}{\partial \tau} = \nabla \cdot (K_{ij}^{S} \cdot \nabla N) - (v_d + U) \cdot \nabla N + \frac{R}{3}\frac{\partial N}{\partial R} \nabla U \tag{1}$$

In this paper, we compose a new 2-D time-dependent model of GCR propagation [8], [9] in the heliosphere including two crucial parameters i.e. in-situ measurements of the solar wind velocity V and strength B of the IMF. Besides, in the present paper we consider one minimum and one maximum epoch of solar activity, separately. For this purpose we performed the superposition of the monthly changes of the solar wind velocity V and the IMF strength B during three years in the minimum 1975-1978 of solar activity and two years 1990-1991 in the maximum of solar activity.

A parallel diffusion coefficient used in modeling is expressed, as: $K_{\parallel} = K_0 K(r) K(R, \alpha)$ where $K_0 = 1.9 \cdot 10^{19} cm^2/s$, $K(r) = 1 + 0.5r/r_0$; $K(R, \alpha) = R^{\alpha}$ contributes to the changes of the parallel diffusion coefficient $K_{\parallel}$ due to dependence on the GCR particles rigidity R. We assume that $\alpha = 0.7$ in the minimum and $\alpha = 1.2$ in the maximum of solar activity [10]. Drift effect due to gradient and curvature of the regular IMF is implemented in the model by means of the ratio of the drift K_d diffusion coefficients to the parallel $K_{\parallel}$ diffusion coefficient $\beta_1 = K_d/K_{\parallel}$. In this model, we consider that a drift effect during the maximum solar activity is scaled down by 30% (almost diffusion dominated case) with respect to the minimum of solar activity (drift dominated case).

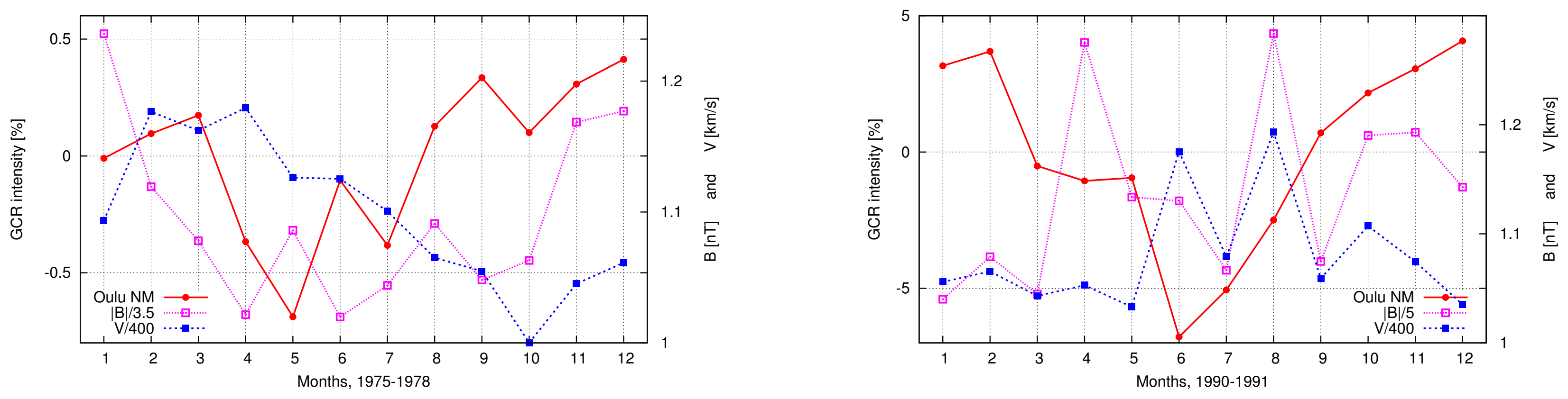

Fig.3ab. Superimposed over years (a) 1975-1978, (b) 1990-1991 monthly changes of the solar wind velocity V and the interplanetary magnetic field strength B and corresponding variations in the GCR intensity based on the Oulu neutron monitor data. To fit one scale the solar wind velocity was scaled down by 400 km/s and IMF strength by 3.5 nT for minimum and 5 nT for maximum.

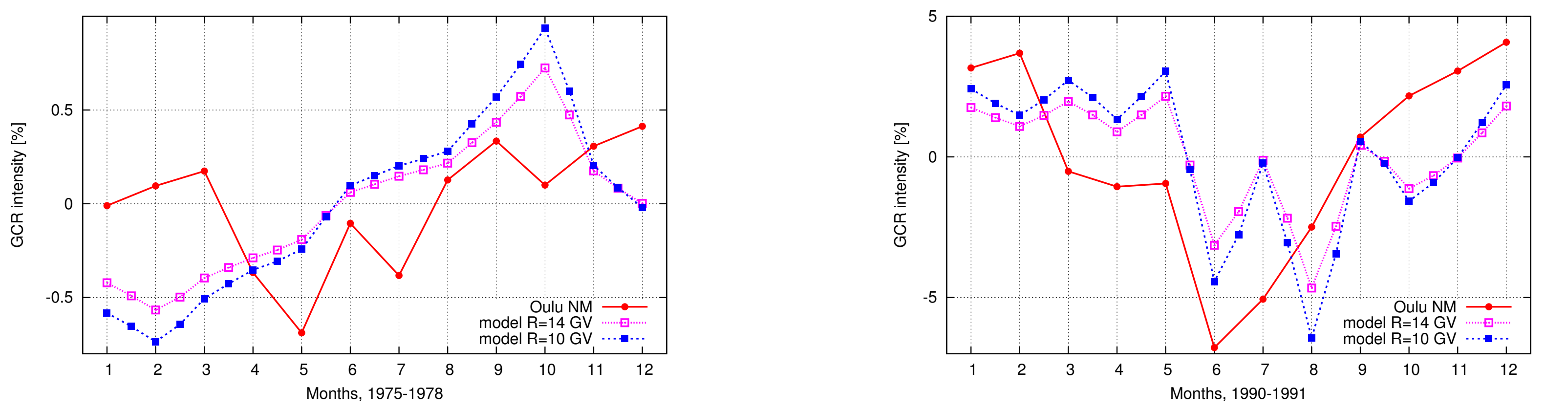

Fig.4ab. The GCR intensity variation for the Oulu neutron monitor (red line) and expected from modeling for rigidity $R = 14$ and 10 GV (magenta and blue line) results for the period of solar activity minimum and maximum.

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