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Galactic cosmic rays flux and geomagnetic activity coupling with cloud covering in Abastumani

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Abstract

The analysis of long-term observations in Abastumani (41.75° N, 42.82° E) revealed differences in the seasonal variations of Galactic Cosmic Rays (GCRs) flux and geomagnetic activities at cloudless days and cloudless nights. Particularly, in summer, the inter-annual distributions of the planetary geomagnetic Ap index and Sudden Storm Commencement (SSC) exhibited minima for cloudless days and maxima for cloudless nights, where GCR flux showed deep minimum. This feature in the case of SSC was demonstrated for the first time. The long-term trends of Ap index during summer time also revealed various meanings for cloudless day and night. These results can be regarded as the effect of cosmic factors on cloud covering in Abastumani, which in turn may have an influence on climatic variations.

1. Introduction

During the last decade the problem of impact of cosmic factors on cloud cover and its consequences on global climate has become of an increasing interest [1]. The solar wind, as well as Galactic Cosmic Rays (GCR) flux, modulated by it, effect the structure of the atmosphere. GCRs are the main source of ionization in the troposphere and lower stratosphere and they can initiate cloud condensation nuclei (CCN) [2, 3]. Geomagnetic storms also affect atmospheric structure and GCR flux [4]. Thus, there should be the interconnection between solar activity, GCR flux and geomagnetic disturbances.

The active processes on the Sun, like energetic proton events, coronal mass ejections (CME), solar flares, etc., are followed by decrease of GCR flux in the heliosphere [5, 6]. Since the active processes happen more often during solar maximum, then in minimum phase, the variations of the GCR flux are in antiphase with the 11-year solar cycle: it's decrease is greater during solar maximum, then during minimum phase [7].

According to Svensmark and Friis-Christensen [2], the lower level cloud covering correlates with the 11-year cycle of GCR flux and can cause variations of the ion numbers produced by it, which in turn affect the changes in the amount of CCN [8]. The cloud covering process is also connected to the temperature and seasonal changes of the atmosphere, in general.

Various seasonal atmospheric conditions can also influence differently the variations of the CCN produced by GCR. Therefore, there is a possibility that the inter-annual changes impact the cloud covering. At the same time, geomagnetic disturbances accompany active processes on the Sun and modulate GCR flux, which may be reflected on the cloud covering processes.

The goal of this paper is to reveal possible influence of cosmic factors on the cloud covering, considering inter-annual and long-term variations of GCR flux, solar activitiy, geomagnetic Ap index and Sudden Storm Commencement and their relationships, at cloudless days and cloudless nights in Abastumani.

2. Inter-annual variations of the planetary geomagnetic Ap index, SSC, GCR and solar radio $F_{10.7}$ fluxes at cloudless days and nights in Abastumani

To reveal the influence of cosmic factors on cloud covering we consider the inter-annual variations of planetary geomagnetic Ap index, Sudden Storm Commencement (SSC), GCR flux and solar radio flux $F_{10.7}$ at cloudless days and nigths in Abastumani.

Fig.1 demonstrates mean seasonal values of Ap index for moderate geomagnetic disturbances (Ap≤49), as well as corresponding normalized GCR flux and solar radio $F_{10.7}$ flux in Abastumani during 1957-1993, for cloudless days (white circles) and nights (black circles). GCR values X (at days with Ap≤49) are normalized to their mean $\overline{X}$: $X_n = (X - \overline{X}) / \overline{X}$.

Fig.1a demonstrates that, for cloudless nights, in addition to the Ap's well-known semi-annual variations with greatest values in spring and fall [9], it also reveals maximum in summer. This indicates the influence of cosmic factors on cloud covering. For the same cloudless nights GCR flux drops in summer as well. This decrease can cause reduction of ionization in the lower atmosphere and, consequently, the decrease of the amount of cloud formation nuclei, which in turn results in more cloudless nights.

The reduction of GCR flux in Summer is even more evident for strong geomagnetic disturbances (Ap≥50), which is often accompanied by Forbush decrease of GCR [6, 10]. The GCR effect on cloud covering appears even stronger since solar radio flux changes (at Ap≤49) in summer for cloudless nights are insignificant.

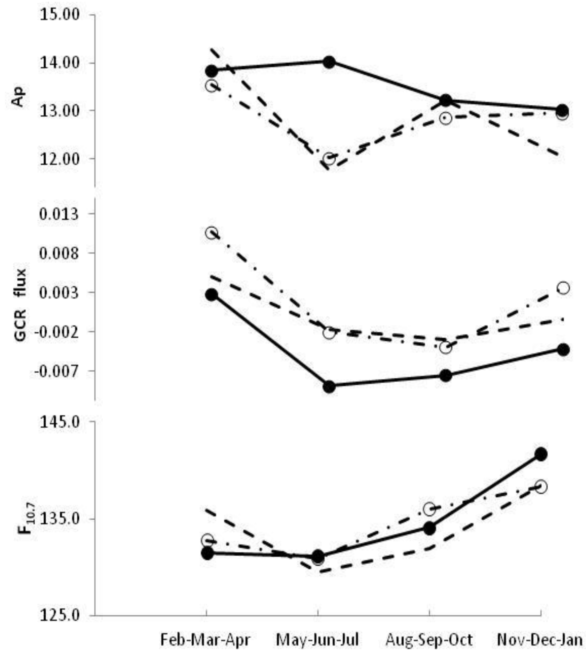

Fig. 1. The inter-annual distributions of seasonal mean values of the following quantities at the planetary geomagnetic Ap≤49: (top panel) *Ap* index; (middle panel) the normalized GCR flux observed by Tbilisi neutron monitor during 1964-1993 and (bottom panel) solar radio flux $F_{10.7}$. Dashed lines are for all day-night periods, dash-dotted lines and white circles – for cloudless days, and solid lines and dark circles – for cloudless nights at Abastumani in 1957-1993.

We considered the inter-annual distributions of monthly mean values of relative monthly numbers of Sudden Storm Commencement (SSC) and normalized GCR flux observed by Tbilisi neutron monitor during 1964-1993, for all, cloudless days and cloudless nights (Fig.2). Relative monthly numbers of SSC (characteristic frequency of SSC occurence) is a ratio of number of days (nights) with SSC to number of days (nights), for every month, summed during 1957-1993. Similar to above case, for cloudless nights, the sharp maximum of SSC in June is accompanied by the deep minimum of GCR flux.

The observed different sensitivity of cloud covering to the cosmic factors during day and night should affect the radiation balance on the Earth's surface and possibly the climate. To reveal the influence of cosmic factors on climate change we will consider the long-term trends of geomagnetic index for cloudless days and nights in the next chapter.

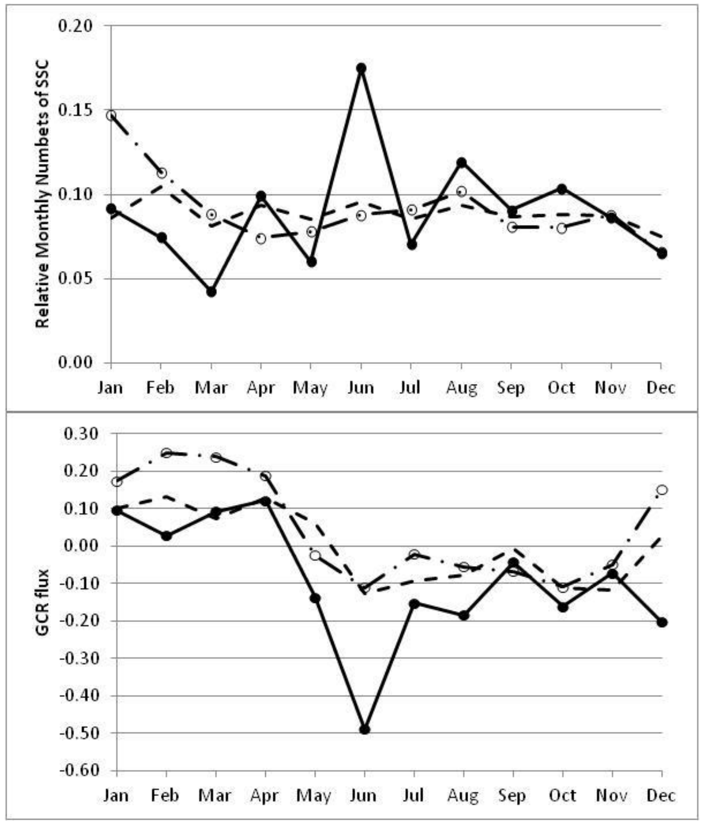

Fig. 2. The inter-annual distributions of monthly mean values of the following quantities: (top panel) relative monthly numbers of Sudden Storm Commencement; (bottom panel) the normalized GCR flux observed by Tbilisi neutron monitor during 1964-1993. Dashed lines are for all day-night periods, dash-dotted lines and white circles – for cloudless days, and solid lines and dark circles – for cloudless nights at Abastumani in 1957-1993.

3. Long-term trends of the planetary geomagnetic Ap index for cloudless days and nights

Like solar activity, the number of geomagnetic disturbances and thus planetary geomagnetic Ap index undergo changes with 11-year, secular and possibly other long-term periods, typical for solar variabilities. The considered dataset covers three 11-year solar cycles [11]. In Abastumani, the monthly and seasonal long-term trends (during 1957-93) in the red line of nightglow intensity were determined [12]. For this period the annual mean values of Ap index experience a minor positive trend. Almost the same values are obtained for cloudless days and nights. On Fig.3 the trend values of Ap for cloudless days, nights and all day-nights at moderate geomagnetic disturbances (Ap≤49) are demonstrated.

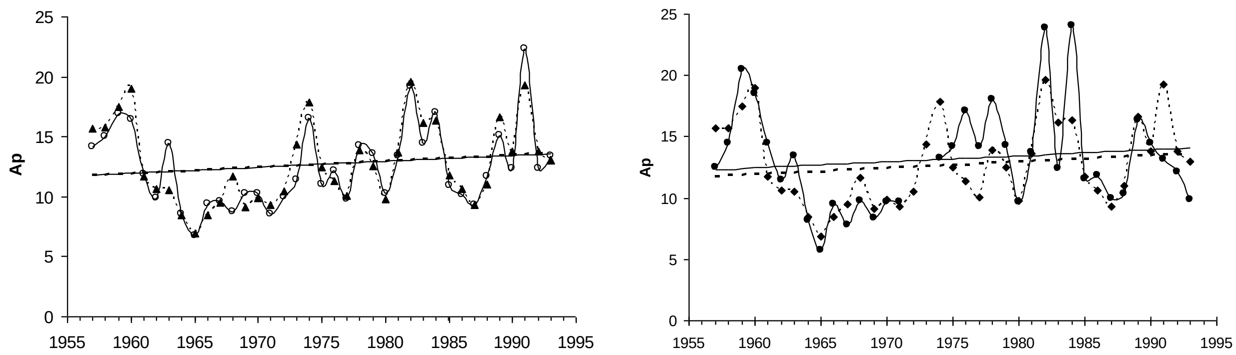

Fig. 3. Long-term variations of the mean annual planetary geomagnetic *Ap* index with *Ap≤49* for all day-nights (dashed lines and triangles), cloudless days (left fig., white circles), cloudless nights (right fig., dark circles) and their linear long-term trends during 1957-1993.

However, for seasonal mean Ap the trends are significantly different in case of cloudless nights. In the table, Ap seasonal trends (year^{-1}) and errors in 95% confidence are presented for all day-nights, cloudless days and cloudless nights.

	All Ap		Cloudless days Ap		Cloudless nights Ap	
	trend	±95% c.i.	trend	±95% c.i.	trend	±95% c.i.
Feb-Mar-Apr	0.092	0.017	0.136	0.036	0.178	0.065
May-Jun-Jul	0.009	0.014	0.008	0.023	-0.104	0.044
Aug-Sep-Oct	0.056	0.016	0.058	0.024	0.091	0.038
Nov-Dec-Jan	0.070	0.015	0.034	0.033	0.072	0.056

For cloudless days and nights these trend values are significantly different in summer (May-Jun-Jul): 0.008±0.023 and -0.104±0.044, respectively, with statistically significant negative number for nights. This negative trend for cloudless nights indicates the decrease of number of magnetically disturbed cloudless nights and thus the reduction of loss of infrared radiation emitted by the Earth's surface. This phenomenon may indicate the impact of cosmic factors on climate change.

4. Conclusion

We obtained different inter-annual variations of planetary geomagnetic Ap index (Ap≤49) and Sudden Storm Commencement at cloudless days and nights in Abastumani. For cloudless nights, mean seasonal Ap and SSC are the greatest in summer, while it is the smallest for cloudless days. In the case of SSC, this feature is demonstrated for the first time in the present paper. So, the effect for weak and moderate geomagnetic disturbances (Ap≤49) and strong ones are similar. The GCR flux decrease is also the greatest in summer.

We obtained that for summer season, the long-term trend of Ap for cloudless nights is significantly different from the one for cloudless days.

The obtained different seasonal sensitivity of cloud covering process to geomagnetic activity and GCR flux changes indicates the impact of cosmic factor on radiation balance on the Earth's surface. This fact, as well as different long-term trends of geomagnetic disturbances for cloudless days and nights, also point on possible cosmic factor influences on climatic variations.

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Referencecs

[1] Gray, L. J., et al. *Rev. Geophys.*, 2010, 48, RG4001.
[2] Svensmark, H., Friis-Christensen, E., *Journal of Atmospheric and Solar-Terrestrial Physics,* 1997, 59, 1225–1232.
[3] Tinsley, B.A., Zhou, L., Plemmons, A., *Atmos. Res.*, 2006, 79, 266-295.
[4] Laštovička, J., *Journal of Atmospheric and Terrestrial Physics*, 1996, 58, 831–843.
[5] Kniveton, D.R., *Journal of Atmospheric and Solar-Terrestrial Physics,* 2004, 66, 1135-1142.
[6] Kudela, K., Brenkus, R., *Journal of Atmospheric and Solar-Terrestrial Physics*, 2004, 66, 1121-1126.
[7] Pudovkin, M.I., Veretenenko, S.V., *Advances in Space Research***,** 1996, v.17, Issue 11, 161–164.
[8] Marsh, N.D., Svensmark, H., *Physical Review Letters,* 2000, 85, 5004-5007.
[9] Russell, C.T., McPherron, R.L., *Journal of Geophysical Research,* 1973, 78(1), 92-108.
[10] Todua, M., Didebulidze, G.G. *Acta Geophysica*, 2013, 62, Issue 2, pp.381-399
[11] Megrelishvili, T. G., Fishkova, L. M., *Izvestiia, Fizika Atmosfery i Okeana*, 1982, 18, p. 1114-1120.
[12] Didebulidze, G. G.; Lomidze, L. N.; Gudadze, N. B.; Pataraya, A. D.; Todua, M., International *Journal of Remote Sensing*, 2011, v.32, issue 11, pp. 3093-3114.

Связь потока галактических космических лучей и геомагнитной активности с облачностью в Абастумани

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Резюме

Анализ продолжительных наблюдений в Абастумани выявил различия сезонных вариаций потока галактических космических лучей (GCR) и геомагнитной активности для ясных дневных и ночных времен суток. В частности, в летнее время, годовые распределения планетарного геомагнитного индекса Ap и внезапного начала бури (SSC) имеет минимальное значение во время ясных дней и максимальное во время ночей. В то же время, в случае ясных ночей, поток GCR имеет глубокий минимум. Для SSC эта особенность была

продемонстрирована впервые. Продолжительные тренды Ap индекса также выявили различные значения в летнее время для ясных дней и ночей. Полученные результаты могут быть проявлением влияния космических факторов на облачность в Абастумани, которое, в свою очередь, может иметь воздействие на климатические изменения.

გალაქტიკური კოსმოსური სხივების ნაკადისა და გეომაგნიტური აქტივობის კავშირი ღრუბელდაფარვასთან აბასთუმანში

მაია თოდუა და გოდერძი დიდებულიძე

აბასთუმნის ასტროფიზიკური ობსერვატორია
ილიას სახელმწიფო უნივერსიტეტი

რეზიუმე

აბასთუმანში წარმოებული გრძელვადიანი დაკვირვებების ანალიზმა აჩვენა, რომ გალაქტიკური კოსმოსური სხივების (GCR) ნაკადისა და გეომაგნიტური აქტივობების სეზონური ყოფაქცევა უღრუბლო დღეებისა და უღრუბლო ღამეების შემთხვევაში განსხვავებულია. კერძოდ, ზაფხულში, პლანეტური გეომაგნიტური Ap ინდექსისა და ქარიშხლების უეცარი დაწყების (SSC) შიდაწლიური განაწილებები უღრუბლო დღეების შემთხვევაში მინიმალური, ხოლო უღრუბლო ღამეების დროს მაქსიმალური მნიშვნელობებით ხასიათდება. ამავე დროს, უღრუბლო ღამეების შემთხვევაში, GCR-ის ნაკადმა მკვეთრი მინიმუმი გამოავლინა. SSC-ის შემთხვევაში ეს თავისებურება პირველადაა დაფიქსირებული. Ap ინდექსის გრძელვადიანი ტრენდები ზაფხულის პერიოდში ასევე განსხვავებული აღმოჩნდა უღრუბლო დღეებისა და ღამეებისათვის. ეს შედეგები შესაძლოა მიუთითებდეს კოსმოსური ფაქტორების გავლენას ღრუბელთდაფარვაზე აბასთუმანში, რაც, თავის მხრივ, შესაძლოა აისახოს კლიმატის ცვლილებებზე.