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The inter-annual distribution of cloudless days and nights in Abastumani: Coupling with cosmic factors and climate change

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ABSTRACT

We examined inter-annual variations and long-term trends of cloudless days (CD) and cloudless nights (CN) in 1957–1993 from Abastumani (41.75N, 42.82E), at different geomagnetic conditions and corresponding galactic cosmic rays (GCRs) flux changes. It showed possible influence of cosmic factors on cloud covering processes and, thus, climate change. It was demonstrated that (1) the inter-annual distribution of monthly mean values of planetary geomagnetic index *Ap* (for low and moderate disturbances) at CDs can be described by harmonic function with semiannual (with sharp maxima in March and September) and annual (with maximum in August) periodicities; (2) the inter-annual distribution of *Ap* index for CN has an additional maximum in June, where the largest decrease of GCR flux is observed. This phenomenon is expressed even stronger during Sudden Storm Commencement (SSC) events and strong geomagnetic disturbances ($Ap \geq 50$), when their relative numbers are the greatest and are accompanied by bigger reduction of GCRs flux; (3) the long-term trends of mean annual and mean seasonal values of *Ap* index and GCRs flux at CD and CN are estimated. It was detected that, for the latitudes of this region, long-term decreases (negative trends) of seasonal GCR flux are different at CD and CN, which could affect the radiative balance at the Earth's surface and, as a result, contribute to the climate change.

1. Introduction

Different variations of cloud covering during day- and night-time can have an effect on the radiative balance at the Earth's surface of a given region. This outcome is caused by different influence of clouds: during day-time they reflect the solar visual electromagnetic radiation, reducing its absorption by the Earth's surface, while during night-time they scatter and partly send back the Earth's infrared thermal radiation. This may have a significant impact on the Earth's radiative forcing and thus on the climate (Gray et al., 2010 and references therein). Therefore, it is important to consider inter-annual (seasonal) and long-term variations of cloudless days (CD) and cloudless nights (CN), which is the purpose of this study.

The clouds at various height levels may react on seasonal changes in atmospheric parameters in different ways, which could be caused by several factors, including cosmic ones (Marsh and Svensmark, 2000; Harrison and Carslaw, 2003; Tsonis et al., 2014). The presented study of inter-annual distributions and long-term changes of cloudless days and nights at various helio-geophysical conditions could contribute to the issue of possible impact of cosmic factors on cloud covering processes and its importance for climate change. For example, the long-term increase of the number of CD should enhance the absorption of solar EM radiation by the Earth's surface, while the decrease of the number of CN would reduce the loss of its thermal IR radiation.

To reveal possible input of cosmic factors in the inter-annual and long-term changes of CD and CN, it is important to consider them for various geomagnetic disturbances, as well as solar activity and galactic cosmic rays (GCRs) flux variations. All these events, followed by some structural and possible dynamical changes of the atmosphere (Todua and Didebulidze, 2013), are coupled to each other and are important to reveal cosmic factors. Geomagnetic disturbances mainly follow active processes on the Sun and are expected to coincide with GCR flux decrease (Kudela and Brenkus, 2004). It is believed that GCRs are main source of ionization in the lower stratosphere and troposphere, below 30 km heights from the Earth's surface, and the reduction of its flux could decrease the amount of cloud condensation nuclei (Tinsley et al., 2006; Usoskin et al., 2009; Mishev et al., 2012). Cosmic rays determine the ionization rate and conductivities in the atmosphere and the ionosphere (below 90 km) and thus the atmospheric electric fields. The latter influence thunderstorms, the Earth's global charge and global electric circuit between the ionosphere and the ground (Velinov, 2006). Thus, there could be a correlation between geomagnetic disturbances, as well as their

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consequent structural and dynamical changes and cloud covering processes in the lower atmosphere. The coupling between GCRs flux variations and geomagnetic activity also may be caused by changes in the GCR cut-off rigidity during these disturbances (Dorman, 2009).

This phenomenon, as well as the dependence of the frequency of occurrence of geomagnetic disturbances (with maxima at equinoxes) on the geometry of the interplanetary magneric field (IMF) and geomagnetic dipole (Russell and McPherron, 1973), can affect inter-annual variations of some atmospheric processes, as well as regional peculiarities of their development. GCRs flux changes following these geomagnetic disturbances can cause structural changes in the lower atmosphere. This can be reflected in the inter-annual variations of cloud covering, which are presented at some extent in the results of the current study.

To study the influence of these factors on cloud cover and consequent climate change, it is also important to consider long-term changes of CD and CN at various geomagnetic and solar activities, as well as at GCRs flux variations. These studies can develop the assumption that the centennial increase of solar activity (Mursula and Martini, 2006) is accompanied by decline in the GCR flux-the negative trend (Rouillard and Lockwood, 2007), that can cause the reduction of cloud covering and as a result can contribute to the global warming observed during last century.

In the present study we consider the inter-annual and long-term variations of cloudless days and cloudless nights in Abastumani for different levels of geomagnetic disturbances (described by planetary geomagnetic *Ap* index), corresponding day–night solar activity (described by solar radio flux $F_{10.7}$) and GCRs flux changes. For the considered dataset, mean annual and mean seasonal *Ap* index and GCR flux trends for CD and CN will be estimated. Different changes of inter-annual/seasonal distributions of monthly mean *Ap* index and corresponding GCR flux will be determined, pointing at possible impact of cosmic factors on cloud cover process. Different seasonal negative trends of GCR flux for CD and CN also indicate cosmic factors influence on climate change in the considered region.

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

To reveal the influence of cosmic factors on cloud covering, in this section we consider the inter-annual distributions of the planetary geomagnetic *Ap* index, GCRs flux and solar radio flux F10.7 changes for CD and CN in Abastumani Astrophysical Observatory (AAO; 41.75N, 42.82E; 1600 m height a.s.l.), using the continuous data of CD and CN, covering three 11-year solar cycles (1957–1993 years). During this period atmospheric studies by optical methods had been carried out almost continuously at AAO. Total ozone content had been observed during days, as well as nightglow observations at different wavelengths had been performed during lunarless nights. The observations required clear sky conditions during both day and night, which were estimated visually. Visually clear conditions in the whole field of view from the observatory are essential for middle and upper atmosphere monitoring by optical methods, which covers the area of almost 15–20 km in the troposphere (Megrelishvili, 1981; Fishkova, 1983). Within the referred period, the total number of CD was 4323 and that of CN was 1534. Nightglow observations had been carried out only at lunarless cloudless nights. On Fig.1 the histogram of interannual distribution of the total monthly numbers of CD and CN in Abastumani (white and black columns, respectively) within the period 1957–1993 are presented. Total monthly numbers of CD vary from 227 to 531, while those of CN from 78 to 199. The portion of visually cloudless days in the whole field of view is about 34% and that of nights at lunarless conditions is about 12% for the considered dataset. A large part of these data is available at www.woudc.org. This dataset allows us to investigate characteristics of the inter-annual (seasonal) distributions of CD and CN and examine them at different helio-geophysical conditions.

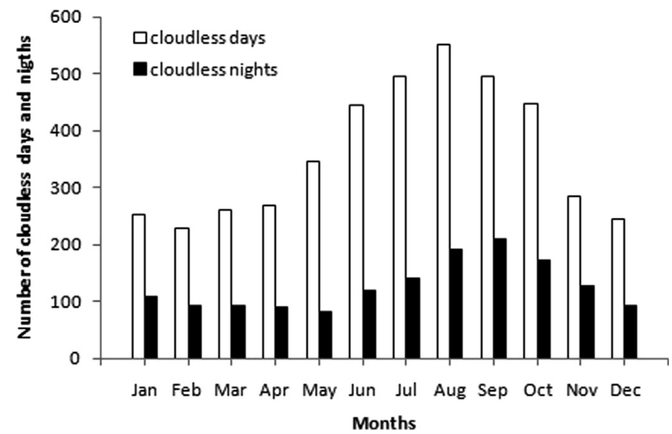

Fig. 1. The histogram of interannual distribution of total monthly numbers of cloudless days (white columns) and cloudless nights (black columns) in Abastumani within the period 1957–1993.

These data had been used to investigate different atmospheric parameters and their long-term variations by various authors (Megrelishvili, 1981; Fishkova, 1983; Givishvili, et al. 1995; Gudadze et al., 2008; Didebulidze et al., 2011). In recent study (Todua and Didebulidze, 2013) the coupling of inter-annual/seasonal variations of some nightglow parameters with solar and geomagnetic activities were considered. It was demonstrated that they may be coupled with night-time cloudiness in the lower atmosphere.

Fig. 1 demonstrates the different interannual/seasonal variations of CD and CN. For example, the maximum number of CDs is in August, while that of CNs is in September. Since number of days in months slightly vary, we studied characteristics of the inter-annual variations of monthly mean values of various parameters (*Ap*, F10.7, GCRs), as well as relative numbers of CD and CN.

As a proxy of geomagnetic disturbance we use the planetary geomagnetic *Ap* index, which at some extent correlates with dynamical and structural changes of the mid-latitude atmosphere–ionoshere (Sinnhuber et al., 2012; Pancheva and Mukhtarov, 2011). We use this dataset to consider inter-annual distribution of the monthly mean planetary geomagnetic *Ap* index, GCRs flux changes and solar radio flux $F_{10.7}$, at CD and CN, for $Ap < 50$ (including quiet $0 \le Ap \le 7$, unsettled $8 \le Ap \le 15$, active $16 \le Ap \le 29$ and minor storms $30 \le Ap \le 49$, www.astrosurf.com/luxorion/qsl-perturbation5.htm).

Here, only 3.4% of day–nights are accompanied by strong geomagnetic disturbances ($Ap \ge 50$). For 96.6% data with $Ap < 50$ some regular inter-annual and long-term variations of the atmospheric parameters should be noticeable in their inter-annual distributions. The cases of sudden storm commencements (SSC) and strong geomagnetic disturbances with $Ap \ge 50$ also will be considered, where atmospheric changes caused by solar–terrestrial coupling processes should be more expressed.

At first, we consider CD and CN with $Ap < 50$ and demonstrate the inter-annual variations of monthly mean values of the following quantities (Fig. 2): geomagnetic planetary *Ap* index (first panel from the top), solar radio $F_{10.7}$ flux (second panel), GCRs fluxes (third and fourth panels). The values are calculated for all day–nights (dotted line), cloudless days (circles) and cloudless nights (dots) in Abastumani. For *Ap* and $F_{10.7}$ the data are taken within 1957–1993 time interval. GCRs flux data had been taken