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Disturbance of a Glow in the Night Sky in Clear Weather at Middle Latitudes

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Abstract—A glow in the night sky is registered at 43° north latitude during global magnetospheric disturbances. The glow is preceded by seismic activity generating an underground negative charge over the Earth's surface with a positive current of 20–25 nA/m^2.

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INTRODUCTION

On the night of 1–2 September 2019, the Mt Aragats experiment recorded a bright continuous glow in thunderclouds [1]. This glow was accompanied by a strong disturbance in the intensity of gamma rays generated by electric field. This effect occurred when there was no rain, so questions of the source of its energy and the underlying process naturally arises. Geographically, Mt Aragats and the Baksan Neutrino Observatory (BNO) are located in one region of the Caucasus and separated by a distance of 340 km. The aim of this work was to determine what happened at the BNO during this period.

EXPERIMENTAL

A set of instruments for studying variations in cosmic rays during thunderstorms is based on the Carpet Air Shower Array at the BNO (43.3° north latitude, 42.7° east longitude). The array is located in a mountain valley at an altitude of 1700 m a.s.l. with a nearby river 40 m away. On both sides of this river are opposing mountains of almost equal heights (4 km a.s.l.), the tops of which are 4–5 km from the observation site.

The Carpet Array continually measures secondary cosmic ray fluxes. Using variations in the fluxes during thunderstorms and the procedure developed in [2, 3], we can determine differences in the potential of the tropospheric electric field both above and away from the array in a ring with radii of 10 to 20 km. The error in this procedure is around 20%. Using a single-frequency six-channel GPS170PCI satellite clock that provides precise temporal signals in real time upon request from the GPS satellite constellation, we can determine the total electron content (TEC) of the ionosphere above the array. Time L spent in executing the command is measured in the experiment at a sampling rate of 5 s^{-1}. Using data from global maps of the ionosphere [4], correlation analysis, and direct calibration of perturbations in measured delays according to TEC disturbance during the development of the magnetic storm, we obtained the coefficient of coupling that links a local disturbance in the TEC above the array with the delay in command execution: $\beta_{Ne/\Delta L} = 0.195 \pm 0.009$ [TEC/ns] (1 TEC = 10^{16} electrons/m^2).

The atmospheric pressure, temperature, strength of the electric field near the ground, and the electric current of precipitation are the parameters measured every second. Pulsed electromagnetic noise is recorded as well.

An underground measuring complex belonging to the North Caucasus Laboratory of the Shmidt Institute of the Physics of the Earth is located in a horizontal tunnel 4.5 km from the basic array (see [5] for details). In this work, we used data from a tilt meter station consisting of two high-precision pendulum tilt meters that measure angles of inclination between the planes of the base and horizon plane in the east–west and north–south directions. The elevation above the horizon corresponds to positive values of the probes. The level of the output electric signal is ±0.2 volts per arc sec.

For continuous observation of optical glow above the experimental setup, two remote points with video cameras view the sky from distances of 0.5 km (the village of Neutrino; angles of elevation are 20°–65°

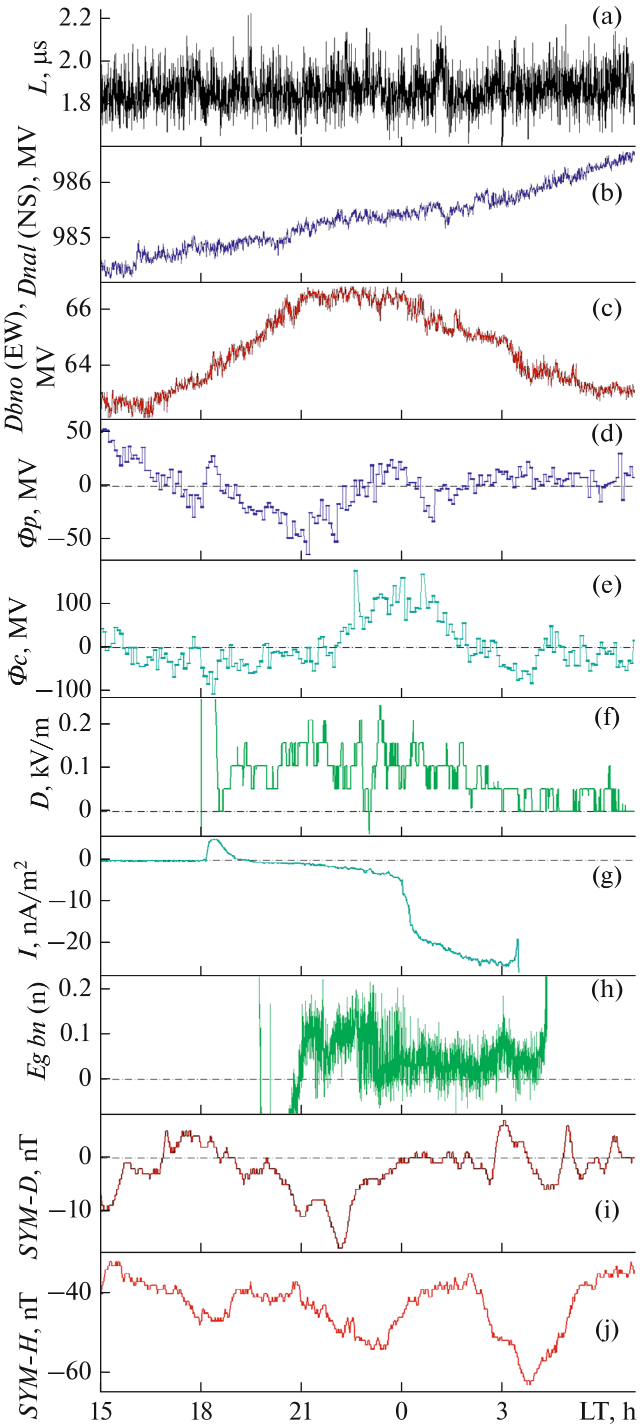

Fig. 1. Event of September 1–2, 2019. Local time 3 h ahead of UT is used. (a) Moment of receiving the exact time signal from GPS satellites; the period of averaging is 20 s. (b) Variations in the ground surface tilt at Nalchik (NS denotes the north–south direction): 1 V corresponds to 5 arcsec, and the period of averaging is 20 s. (c) Variations of the ground surface tilt at the village of Neutrino (EW is the east-west direction): 1 V corresponds to 5 arcsec, and the period of averaging is 20 s. (d) Potential difference in the troposphere 10–20 km away from the array, reconstructed from variations of peripheral muons with an energy threshold of 70 MeV; the period of averaging is 5 min. (e) Difference in the potential of the troposphere above the array, reconstructed from variations in vertical muons with energies of 30–60 MeV; the period of averaging is 5 min. (f) Strength of the electric field near the ground; the period of averaging is 20 s. (g) Electric current of precipitation; the period of averaging is 20 s. (h) Brightness (in channels) of the glow in the central area of the video frame (village of Neutrino; the period of sampling is 10 s); the period of averaging is 20 s. (i) Y-component of the symmetric part of the magnetic field (*SYM-D* index) [7]; the period of sampling is 1 min. (j) X-component of the symmetric part of the magnetic field (*SYM-H* index) [7]; the period of sampling is 1 min.

above the horizon, and the main direction is southward) and 75 km (the village of Khasanya; angles of elevation are 0°–50° above the horizon, and the main direction westward). Each point records luminosity with two video cameras in the optical (camera Cs280) and infrared (camera Cs265) ranges. For quantitative descriptions of luminosity, a functional correlation is determined between the glow of a remote extended surface and the average pixel brightness of its photo image.

RESULTS FROM OBSERVATONS

Figure 1 presents plots of different geophysical parameters whose variations can show what actually took place. A local cloud with a field characteristic of thunderstorms passed by from 17:30 to 18:45 on the evening of September 1, 2019. The strength of the field near the ground is shown in Fig. 1f. The probe of the precipitation's electric current registered the positive current typical of thunderstorms (Fig. 1g). The thundercloud itself was observed by video cameras only in the period from 17:30 to 18:20. The weather was normal with scattered clouds the rest of the time. Stars started to become visible at 20:30. There was no reason to observe the considerable charge in the atmosphere. At the same time, the difference between the potential in the troposphere (estimated from variations of muons) above the array (Fig. 1e) and at the periphery (Fig. 1d) had values typical of thunderstorms throughout the night. Charge waves of different polarities passed by at distances from one another of 10–20 km. We can clearly see traces of pulsed discharges at 21:14, 22:05, and 01:00 in the plot of differences in the potential at the periphery. They were not recorded by the noise channel, which is normal when a discharge is horizontal or slow. The first discharge indicated the start of growth of the large-scale field's positive component. It coincided with the cessation of growth in the tilt of the lithospheric plate in the BNO region (Fig. 1c). The third discharge indicated the beginning of a sharp drop (down to a reversal of polarity) in the difference in the potential above the array. The delay in receiving the signal from the GPS satellite constellation (Fig. 1a) started to increase at the same moment. The disturbance lasted for 20 min, reaching a maximum of 120 ± 3 ns at 01:10. The corresponding TEC increment was 23.3 ± 1.2 TEC. According to measurements made at the town of Nalchik, a break in inclination occurred at 01:05 (Fig. 1b). The electric current of precipitation (Fig. 1g) rose slowly to approximately -1 nA/m^2 during this period. Around midnight, it grew sharply to approximately -20 nA/m^2 under an almost clear sky with stars visible to the cameras. Around 03:00, the BNO cameras recorded increased luminosity throughout the sky (Fig. 1h). The parameters of the glow were measured. The background before the disturbance was intense in red, green, and blue photons with R(630 nm) = 0.33 × $(2^{\pm1})$ kR, G(525 nm) = 1.53 × $(2^{\pm1})$ kR, and B(430 nm) = 4.50 × $(2^{\pm1})$ kR, respectively. In photometric units, $R = 1.51 \times (2^{\pm1}) \times 10^{-5}$ [Cd/m^2], $G = 2.47 \times (2^{\pm1}) \times 10^{-4}$ [Cd/m^2], and $B = 1.31 \times (2^{\pm1}) \times 10^{-5}$ [Cd/m^2], repectively. In total, $2.7 \times (2^{\pm1}) \times 10^{-4}$ [Cd/m^2] corresponds to usual brightness of a moonless night sky; $(2^{\pm1})$ is the methodological error, which was determined via calibration on a logarithmic scale and is identical for all colors. The glow maximum in the form of a sharp peak corresponds to the moment 03:03. The statistically significant maximum amplitude of the disturbance, estimated for the period 03:02–03:04 and expressed in percent portion of background brightness, is $R = (3.53 \pm 0.32)\%$, $G = (3.20 \pm 0.42)\%$, and $B = (4.22 \pm 0.65)\%$. The total effect in photometric units is $0.9 \times (2^{\pm1}) \times 10^{-5}$ [Cd/m^2]. It is not seen by eye. The camera in the village of Khasanya could not see this effect either, due to the background illumination of nearby town. Effective period 02:50–03:20 of the disturbance (full width at half-maximum brightness) coincided with the period of temporary stabilization of the magnetosphere ring current, the dynamics of which is reflected in variations of the *SYM-H* index (Fig. 1j). The glow peak coincided with the maximum inter-hemispheric current (index *SYM-D*, Fig. 1i) and the beginning of a sharp drop in negative readings of the precipitation current meter before 03:30. At this time, the morning dew that forms during fair weather usually upsets the electrical insulation of antenna on the precipitation current meter.

Since stars were seen in the night and dew formed in the morning (i.e., the conditions were those of fair weather), it is clear the fields in the troposphere reconstructed from muon variations and measured by the near-ground field meter were formed by terrestrial charges, and the pulsed discharges occurring at 21:14, 22:05, and 01:00 were underground breakdowns. It was reported in [6] that compressing a granite plate up to 10% of its destructive stress produced electric currents as strong as 50 nA/m^2. Vibration of the lithospheric plate, measured by the BNO tilt meter (Fig. 1c), indicated there was collisional compression. The uniform tilt growing in one direction was reversed, with a period of gradual face crumbling occurring in between. Charges must have separated during this period. The positive charge left the zone of compression while the negative one remained, forming a positive field above the array. Since the duration of plate crumbling (3.5 h) coincided with the period of an anomalous positive current flowing from the ground into the atmosphere, we believe it was the same compressed positive charge. The transport time of 3 h requires explanation. It was apparently this flow to the Earth's surface in Armenia that initiated a seismic thunderstorm and produced a diffuse glow at the BNO.

CONCLUSIONS

A glow in the night sky was recorded against the background of stars during magnetospheric disturbances at 43° north latitude. The period of maximum glow coincided with that of the stabilization of the ring current; its peak value, with the maximum inter-hemispheric current. The glow was preceded by seismic activity generating an underground negative charge with a positive current of 20–25 nA/m^2 that emerged on the Earth's surface. This current was compensated for by the inter-hemisphere current.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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