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Variations in Electric and Meteorological Parameters in the Kamchatka Surface Atmosphere during the Solar Events in October 2003

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Abstract—The daily variations in the electric conductivity, electric-field strength, and meteorological parameters in the surface atmosphere during the solar events in October 21–31, 2003, have been studied. It has been indicated that the conductivity and electric-field strength strongly depend on the air temperature and humidity. It has been found that the conductivity increased for 2 days before the geomagnetic storm on October 29–30 as a result of the effect of solar cosmic rays and decreased during a Forbush decrease in galactic cosmic rays, which was accompanied by a corresponding increase in the electric-field strength. It has been found that the air temperature and humidity anomalously increased in the process of solar activity, which resulted in the formation of different clouds, including thunderclouds accompanied by thunderstorm processes and showers. Simultaneous disturbances of the regular meteorological processes, solar flare series, and emission intensification in the near ultraviolet band, and visible and infrared spectral regions make it possible to consider these processes as a source of additional energy inflow into the lower atmosphere.

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1. INTRODUCTION

The effect of solar and geomagnetic activity on a quasi-static electric field and meteorological parameters in the surface atmosphere at high and middle latitudes was studied comparatively long ago. Many publications have been devoted to this problem (see, e.g., (Paramonov, 1969; Roble, 1985)). Recent works are analyzed in (Smirnov et al., 2013), where it was shown that the obtained data and the proposed mechanisms of the observed effects are contradictory. We selected the geomagnetic storm in October 2003 because it was related to extreme events on the Sun, the manifestation of which in the behavior of the geophysical processes in the Earth's magnetosphere and ionosphere was considered in (Veselovsky et al., 2004; Panasyuk et al., 2004). The effect of this geomagnetic storm in the variations in a quasistatic electric field in the midlatitude surface atmosphere (Swider station, geomagnetic coordinates $\Phi' = 48°$, $\Lambda' = 105°$) was previously considered in (Nikiforova et al., 2005). Negative bays in the electric field potential gradient were registered during the storm main phase under the fine weather conditions. Since the duration of these bays and riometer absorption bursts in the subauroral zone coincided, these authors were able to propose that "the negative values of the electric-field potential gradient may be caused by an increase in the upper-atmosphere conductivity owing to energetic electron precipitation into auroral latitudes" (Nikiforova et al., 2005; p. 152).

The authors of the present paper previously considered the effects of weak (Mikhailova et al., 2009) and extreme (Smirnov et al., 2013) geomagnetic storms in the variations in the electric-field strength and meteorological parameters during the extreme storm that occurred in November 2004.

The present work continues the studies that have been performed at Kamchatka (Paratunka observatory, $\varphi = 52.9°$ N, $\lambda = 158.25°$ E) in this field and have been devoted to studying the solar events that occurred in October 2003. A wide range of different geophysical and meteorological parameters (the quasistatic electric-field strength; air temperature, pressure, and humidity; wind velocity; geomagnetic indices; and simultaneously observed cosmic-ray fluxes and X rays) were also used in this work. In addition, simultaneous recordings of air conductivity were additionally used here, in contrast to (Smirnov et al., 2013).

2. INITIAL DATA AND MAIN RESULTS

It seems reasonable to consider the response of the electric and meteorological processes in the surface atmosphere to a powerful geomagnetic storm using the superposed epoch method together with the processes proceeding on the Sun and near the Earth's surface.

Therefore, Fig. 1 illustrates the observations of different geophysical and meteorological parameters on October 21–31, 2003.

Curves *1* represent the quasi-static electric-field strength (the *Ez* component), measured with the Pole-2 devices accurate to 0.3 V m^{-1} and at a time interval of 1 min, as well as the *Dst* index values (nT) determined at a time interval of 1 h.

Curves *2* and *3* shows the air conductivity separately caused by positive (λ_+) and negative (λ_-) ions and measured with the Elektroprovodnost'-2 device (in conditional units).

Curves *4–8* are the air pressure (*P*, hPa), temperature (*T*, °C), and humidity (%), as well as precipitation and wind velocity (*V*, m/s), respectively. These parameters were measured at a time interval of 10 min at the Paratunka observatory with the WS-2000 and WS-2300 digital weather stations. The output data come to the observatory along the radio channel at a frequency of 433 MHz. The value of the geomagnetic-field horizontal component (*H*) measured at the Paratunka observatory with the FRG-601G fluxgate magnetometer accurate to 0.01 nT at a time interval of 1 min (the right-hand ordinate) is additionally plotted on curve *4*.

Observations of the cloudiness and precipitation state at the local weather station are also used in this
2 work. Unfortunately, actinometric measurements were absent during this period.

Curve *7* shows the 3-h values of the *Kp* index.

Curve *9* corresponds to the galactic cosmic-ray flux (*N* is the number of particles per minute) measured with the neutron monitor at a time interval of 1 min at the IKIR DVP RAN Stekol'nyi observatory.

Curve *10* represents the series of solar flares measured on the GOES-12 satellite (http://goes.ngdc.noaa.gov/data/avg).

In addition to Fig. 1, a more detailed chronological sequence of these events, which was thoroughly described in (Veselovsky et al., 2004), is tabulated, and Fig. 2 shows the series of several most interesting conductivity and field strength fragments recorded on an increased scale depending on universal time (UT). (At the observatory longitude, local noon and midnight are registered at 1:45 and 10:55 UT, respectively.)

We consider in detail the processes proceeding in the surface atmosphere. Figure 1 and table indicate that solar (M9.9 X rays) and geomagnetic ($Kp < 3$) activities were relatively low on October 21 and 22 and the meteorological conditions corresponded to fine weather since altostrati were present and precipitation was absent (*RD* ..., 2002). In this case, the noon temperature on October 21 and 22 was +12°C (Fig. 1, curve *5*), humidity was 45% (curve *6*), and conductivity was ~4000. According to the data of the local weather stations, on that day altostrati were continuous at a gentle wind and in the absence of precipitation, and the variations in the conductivity and electric-field strength were regular, which corresponded to the fine weather conditions (Smirnov, 2013).

On October 22 the daily variations in the conductivity and field strength slightly changed in contrast to the previous day with similar daily variations in the temperature and humidity: the conductivity decreased not so smoothly as a result of a light rain (the data of the local weather station), which carries volume charges to the ground (Imyanitov and Chubarina, 1965). In addition, solid middle clouds (there were ten clouds) apparently resulted in a decrease in the daily average level of the electric-field strength and in attenuation of the sunrise effect. On those 2 days, the daily variations in the temperature and humidity amplitudes (as halves of the difference between the maximal and minimal values) were 7.5–8°C and 22.5%, respectively.

On October 23, the X5.4/1B and X1.1/1N solar flares occurred at 8:17 and 19:50 UT, respectively. The temperature regime in the atmosphere abruptly changed on the next two days: the daily amplitude of the temperature decreased to 5 and 1°C, respectively, due to an anomalous temperature rise at night, and that of the humidity decreased to 0.5 and 2.5%, respectively, owing to an increase in this parameter in daytime. Under these conditions, continuous lower clouds (the amount of clouds was 10) without precipitation appeared on October 25, and these clouds were accompanied by a moderate rain at the beginning of the day on October 24 and, then, by a continuous rain. These meteorological phenomena distinctly manifested themselves in a complex character of variations in the conductivity and electric-field strength.

The X1.2/3B, X1.2/1N, and M7.6/2N solar flares occurred on October 26 at 5:17, 17:17, and 21:26 UT, respectively. After these flares (on October 27 and 28), the daily amplitudes of the temperature were 2 and 2°C, respectively, due to a nighttime temperature rise to +6°C, and those of the humidity were 5 and 10%, respectively, which resulted in the formation of the lower stratocumulus (there were from four to six clouds) but without precipitation. Figure 1 indicates that the conductivity was very high (~4000) and remained almost constant during these two days (Fig. 2c). The daily average electric-field strength was very low (~50 V m^{-1}). Starting at 16:00 on October 28, the conductivity started smoothly decreasing to about 1000 and remained unchanged until 16:00 UT on October 30. In this case, the field strength simultaneously increased to 100 V m^{-1} and also slightly varied during the distinguished period. This period coincided with the time of a deep minimum in the *Dst* variation and Forbush decrease in galactic cosmic rays (GCRs). Lower cumulus clouds (from one to ten clouds) without precipitation were observed on October 29 and up to 6:00 UT on October 30, after which continuous rain started and snow sometimes fell. The corresponding changes typical of precipitation days appeared in the variations in

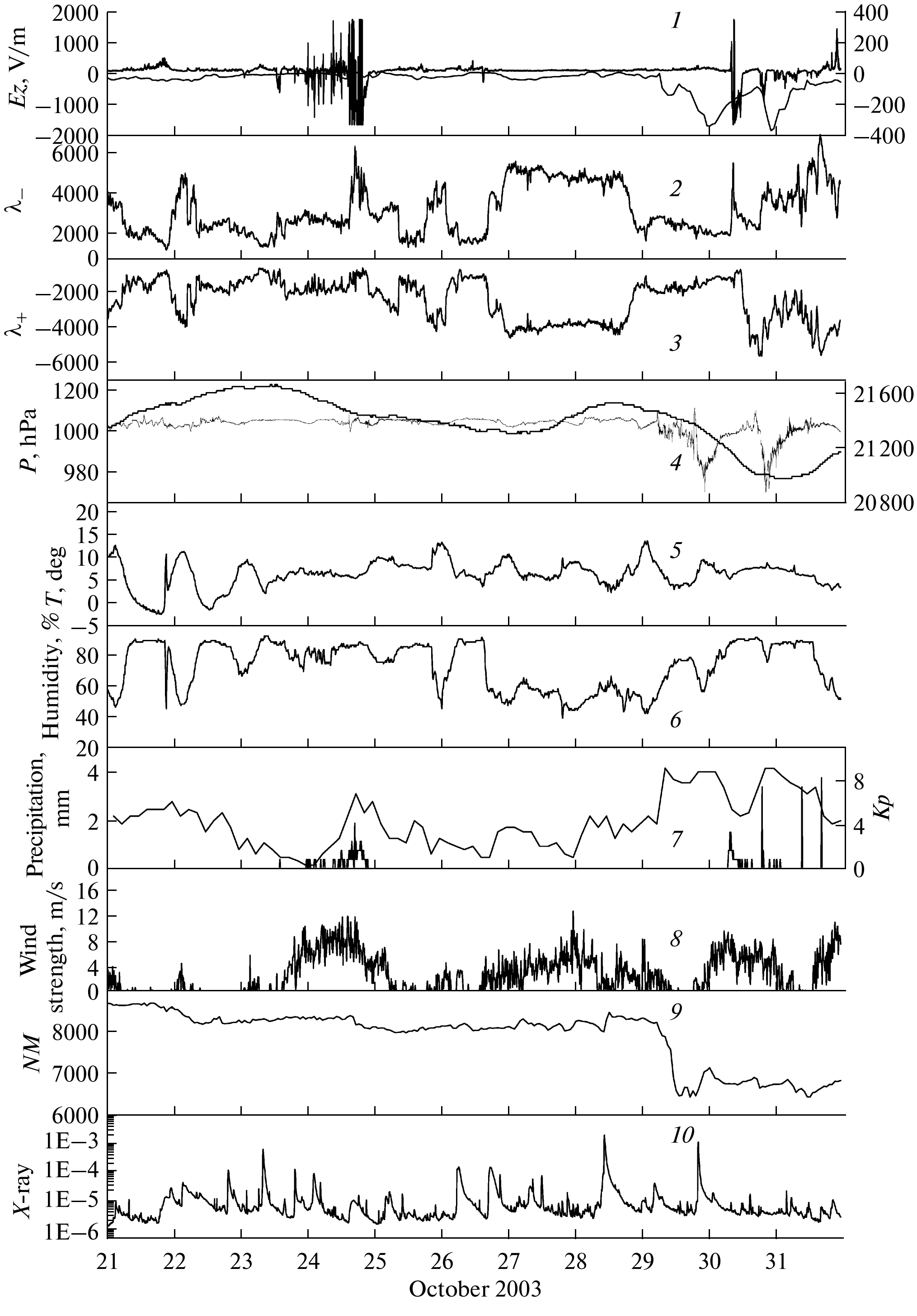

Fig. 1. Daily variations in the air conductivity; electric-field strength; and meteorological, geophysical, and solar parameters on October 21–31, 2003.

the conductivity and electric-field strength (see Fig. 2b, October 24).

During the considered period (October 21–29), the air pressure (Fig. 1, curve *4*) varied from 1000 to 1020 hPa. The pressure dropped from 1010 to 980 hPa after the geomagnetic storm on October 29–31.

3. DISCUSSION OF RESULTS

The variations in the experimentally observed air conductivity as a specific conductivity of the 1-cm^2 air column with height h in a ball condenser is described as follows (Tverskoy, 1949):

$$\lambda = \Sigma n_i u_i e = e\Sigma(n_{\text{л}} u_{\text{л}} + n_{\text{с}} u_{\text{с}} + N u_{\text{т}}),$$

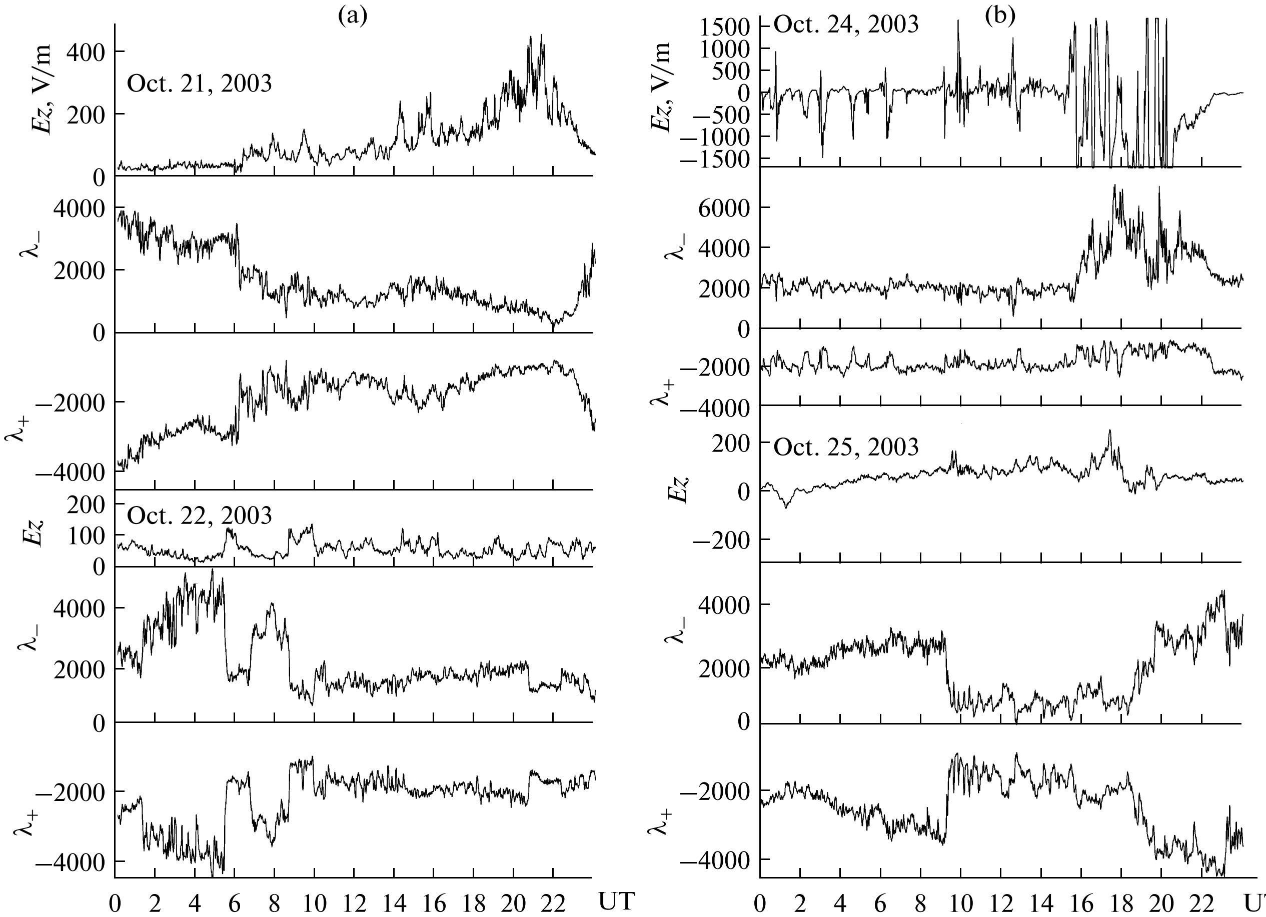

Fig. 2. Daily variations in the electric-field strength and air conductivity during the distinguished periods of observations (a)–(d).

where e is the elementary charge; n_i is the density of the ith-type ions; u_i is their mobility; and N and u_h are the density and mobility of heavy ions, respectively. In the surface atmosphere, the densities of light and medium ions are of the same order of magnitude ($n_i \sim$ 200–300 cm^{-3}), and $N \sim 5000$ cm^{-3}. However, the mobility of medium and heavy ions is factors of 2 and 4 as low as that of light ions. Thus, the air conductivity mostly depends on light ions of both signs: $\lambda = \lambda_+ + \lambda_-$. The density and mobility of light ions depend on the effect of air ionizers and temperature (Bricard, 1965) and on the boundary atmospheric-layer turbulent state, which in turn depends on the atmospheric thermobaric regime (Tverskoy, 1949). Proceeding from these dependences, we can qualitatively explain the conductivity behavior during the period that we are considering. Thus, under the fine weather conditions on October 21 and 22, the conductivity daily variations are in close agreement with the daily variations in the air temperature and humidity: when the temperature is high in the daytime, the conductivity is high (~4000), since the light-ion mobility increases and light ions may be intensely produced owing to the favorable emission of subsoil gases, including radon. The field strength is correspondingly low. When the air temperature decreases, the electric conductivity gradually decreases and remains practically constant (~1000) and slightly fluctuates at night. At that time, the air humidity increased to ~90% in the form of water drops, onto which light ions apparently started precipitating (Fig. 1, curve *6*); as a result, the density of these ions decreased. In addition, the mobility of these ions and the emission of subsoil gases decrease at low temperatures. The electric-field strength correspondingly increases (see Fig. 2a). The minimum in the conductivity daily variations is registered at sunrise owing to the effect of a local convective generator, when ions are transported upward together with heated air. This results in a decrease in the ion density and, correspondingly, in an increase in the electric-field strength (Smirnov, 2013).

The daily average level of the electric-field strength decreases, and the daily variations in this level are disturbed at sunrise in the presence of different clouds, especially lower clouds with mostly negative charges in their lower zone (Imyanitov and Chubarina, 1965). During precipitation that carries volume charges to

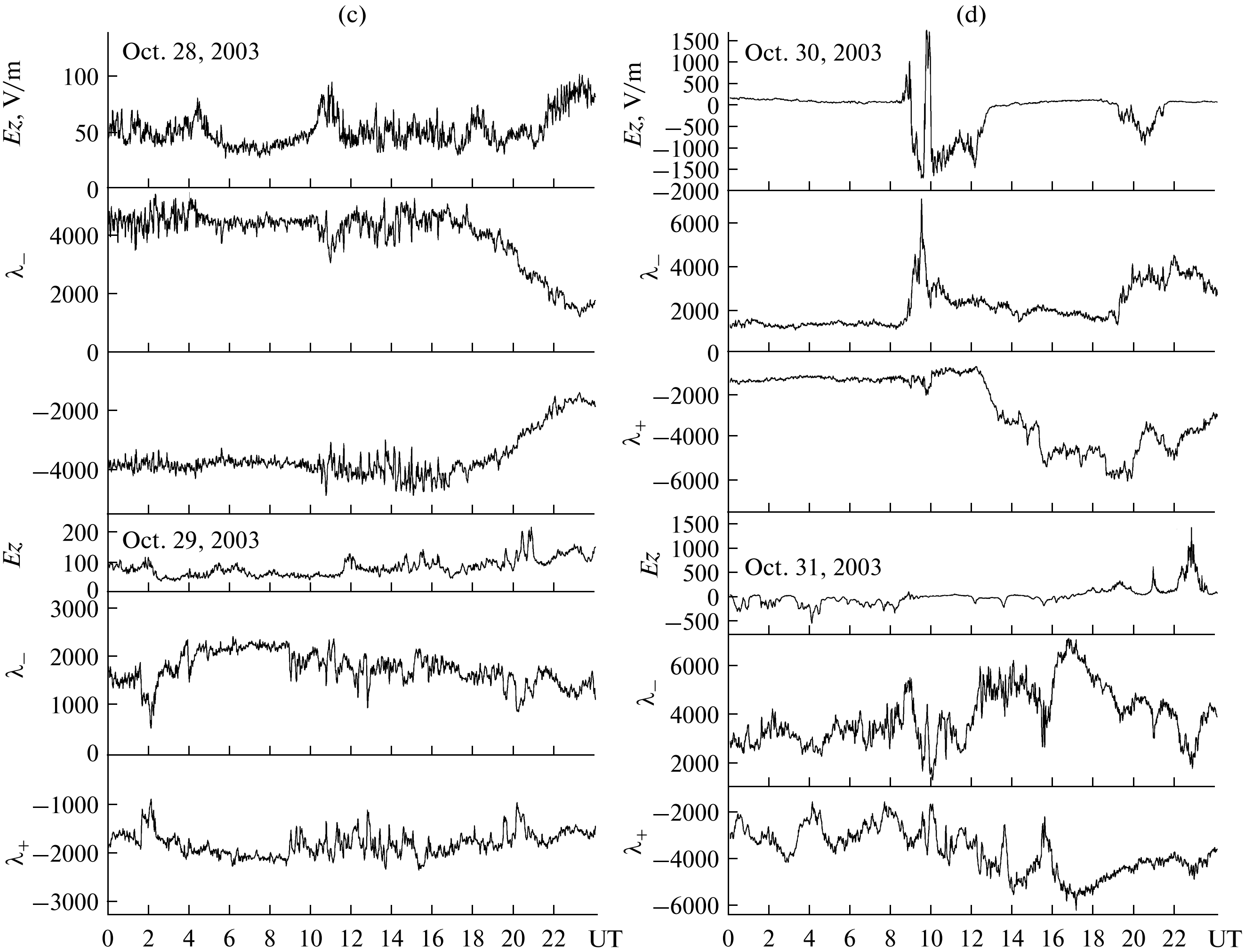

Fig. 2. Contd.

the Earth's surface, the conductivity also abruptly changes (see Figs. 2b, 2d; October 24, 30).

However, global ionizers also constantly operate in the atmosphere in addition to local ones. Solar cosmic rays (SCRs) and GCRs, which strongly vary during solar flares and geomagnetic storms, are among these global ionizers. On October 21–31 (see (Veselovsky et al., 2004), Fig. 22), the flux of SCR nuclei in the Northern Hemisphere increased after the powerful solar flare of October 26 from 1 to $\sim 10^2$ particles/cm^{-2} on October 27 to $\sim 10^3$ particles/cm^{-2} on October 28 and 29 at insignificant GCR variations (see Fig. 1, curve *9*). As is known, in this case, the boundary of the SCR flux cutoff rigidity drops. This resulted in an increase in the density in the upper troposphere and, correspondingly, conductivity in the entire air column. Using this process, we can apparently explain why the conductivity level is constantly high during October 27 and 28. However, the conductivity starts decreasing from 4000 to 1000 at a slight change in the air temperature, remaining unchanged up to 6:00 UT on October 30 (see Figs. 2c, 2d), when the geomagnetic storm and GCR Forbush decrease began at 16:00 UT, which apparently suppressed the effect of SCRs. The field strength simultaneously increased from 50 to 100 V m^{-1}. This time interval coincided with the time of a deep minimum in the *Dst* variation and GCR Forbush decrease. Thus, the global source of atmospheric ionization suppressed the effect of the local sources: the convective generator, clouds, and precipitation.

A more complex situation was observed in the variations in the meteorological parameters, especially in the temperature and humidity. According to the data of the local weather station, clouds changed from upper stratus (October 21–22) to cumulonimbus clouds that were accompanied by thunderstorm processes and rain showers (October 24 and 30). At the same time, (see, e.g., (Matveev, 2000)), it is known that the formation of clouds, especially cumulonimbus ones, is related to additional solar-radiation input, when heated air flows, including water vapor, ascend with increasing temperature and humidity. The varia-

The flare events in ARs 10484 and 10486 on October 19–31, 2003, and their manifestations in the near-Earth space (Veselovsky et al., 2004); the data were taken from the Internet: *Dst* (http://spidr.ngdc.noaa.gov/spidr/); *kp* ((http://wdc.kugi.kyoto-u.ac.ip/cgi-bin/kp-cgi)

Date	Flare		*SC* UT	*Dst*, nT	*Kp*	SCR *E*, MeV P cm^{-2} s^{-1} sr^{-1}	GCR, %	Storm main phase
	UT duration, min	importance						
19	16:29; 79	*X*1.1/1*N*		–40	5–			
22	19:45; >41	*M*9.9		–33	3–			
23	08:17; 64	*X*5.4/1*B*		–21	2		–5	
23	19:50; 38	*X*1.1/1*N*		–11	1–		–5	
24	02:22; 66	*M*7.6/1*N*		–8	1+		–3	
26	05:17; 213	*X*1.2/3*B*		–27	2		–7	
26	17:17; 179	*X*1.2/1*N*		–5	3–	2 10	"	
26	21:26; 60	*M*7.6/2*N*		–16	4–		"	
27	09:21; 23	*M*5.0/1*F*		–49	2		–6	
27	12:27; 37	*M*6.7/1*F*		–41	2		"	
28	09:51; >269	*X*17.2/4*B*		–30 –80	4+ 8–	1 1000	–10	
29	20:37; 136	*X*10.0/2*B*		–233	9–	"	–5 –25	14.00– 29
30				–350	9–	"	–15	00.01 30 τ = 11 h
30				–100	9	"	–22	18.00– 30
30				–383	9	"	–24	23.00 30 τ = 5 h

tions in these parameters are clearly shown in Fig. 1 (curves *5*, *6*) on October 24–25 and 27–28—namely, the daily amplitudes of the temperature and humidity decreased on that days to 5°C and 0.5%, respectively, as compared to such parameters under the fine weather conditions on October 21–22 (7.5–8°C and 22.5%) since the nighttime temperature considerably increased, which was accompanied by a simultaneous increase in the air humidity. This experimental fact indicates that a considerable additional solar irradiance actually came into the lower atmosphere even in the presence of clouds that decreased atmospheric transparency. Since these periods coincided with the times of solar-flare occurrence on October 23 and 28,

we can assume that the daily anomalies of the air temperature and humidity were caused by high solar activ-
1 ity. As is known, during solar flares, solar irradiances increase not only in the X-ray band as an indicator of the flare intensity, but also in a wider band (Fletcher et al., 2011), especially in the cases in which flares occur near the solar-disk center, as was observed in October 2003 (Woods et al., 2004). According to the data of the NASA Solar Radiation and Climate Experiment (SORCE) spacecraft, on October 28 the total solar irradiance increased by a factor of approximately 50 as compared to the irradiance before the flare. The near-ultraviolet ($\lambda \sim 200$ nm) and visible spectral regions account for about 50% of the total radiation energy (Woods et al., 2006). It was also found that the IR irradiance at $\lambda = 1.553$ μm also significantly increased (Fontenla et al., 2004). Only part of the total radiation spectrum comes into the lower atmosphere through the so-called transparency window. This window includes the near ultraviolet and the visible band ($\lambda = 1000 - 2 \times 10^4$ Å, 100–2000 nm), i.e., the solar-radiation intensity maximum (see, e.g., *Fizika* ..., 1986; p. 39), and the IR band ($\lambda = 1$–20 μm). Precisely in this radiation band, an additional heat apparently came during the solar flares in October 2003. (We do not consider atmospheric-transparency variations depending on geomagnetic activity observed at subau-
2 roral observatories (Pudovkin, 1996) since actinometric measurements were absent at the Paratunka observatory.)

White-light flares can also be considered an additional source of the thermal radiation that came into the Earth's atmosphere from October 21 to October 31. This radiation includes a continuous spectrum in a wide wavelength range. The radiation maximum lies in the 360–400 nm band (Neidig, 1989), and the pulse maximum of this radiation is on the same order of magnitude as that of the soft X-ray band (Hudson, 1983) and can penetrate into the lower atmosphere. White-light flares were registered on October 23 when the X-ray intensity was M2.4 (i.e., when the impulsive flare was moderate) at 2:35:00 UT with a prolonged smooth high-intensity component (Hudson et al., 2006). A white-light flare was also registered on October 28 and 29, but the X-ray intensity was substantially higher at that time (X17/4B and X10/2B, respectively). Moreover, the emission intensity in the IR tail of the flare spectrum also increased (Maurya and Ambastha, 2009). These flares could probably contribute to the disturbance of the temperature and humidity daily variations.

It was of special interest that the normal daily variations in the air temperature and humidity recovered on October 29 when the wind velocity decreased to 2 m/s in the absence of precipitation, i.e., when there were fine weather conditions. We can explain this phenomenon taking into account the irradiance registration on the SORCE spacecraft, when the emission intensity in the visible wavelength range ($\lambda = 300$–2000 nm) decreased owing to the presence of sunspots on the solar disk (Woods et al., 2004).

It is also interesting that a negative daily pressure drop (~30 hPa) was observed on the second day after the geomagnetic storm.

4. CONCLUSIONS

The studies of the daily variations in the air conductivity, electric-field strength, and meteorological parameters in the Kamchatka surface atmosphere during the solar events of October 2003 made it possible to draw the following conclusions.

1. The daily variations in the conductivity and electric-field strength demonstrated that these variations strongly depend on the air temperature and humidity. This conclusion coincides with previously known results (see, e.g., (Popov, 2008)).

2. We found that the air conductivity increased during 2 days before the geomagnetic storm of October 29–30 owing to the effect of SCRs and decreased during the GCR Forbush decrease with the corresponding increase in the electric-field strength.

3. The observed anomalous increase in the temperature and humidity during the development of solar activity resulted in the formation of different clouds, including cumulonimbus ones, that are accompanied by showers and thunderstorm processes.

4. Since the periods with disturbed regular meteorological processes coincide with series of powerful solar flares that are accompanied by intensification of near-UV, visible, and IR emissions, we can consider these emissions as a source of additional thermal energy income into the lower atmosphere.

5. We found the negative daily pressure drop on the second day after the geomagnetic storm of October 29–30.

6. All the conclusions drawn above coincide with the results of detailed analysis of the solar events in November 2004 (Smirnov et al., 2013).

REFERENCES

Bricard, J., Action of radioactivity and of pollution upon parameters of atmospheric electricity, in *Problems of Atmospheric and Space Electricity*, Amsterdam: Elsevier, 1965.

Fizika kosmosa (Space Physics), Moscow: Sovetskaya Entsiklopediya, 1986.

Fletcher, L., Dennis, B.R., Hudson, H.S., et al., An observational overview of solar flares, *Space Sci. Rev.*, 2011, vol. 159, pp. 19–106. doi:10.1007/S11214-010-9701-8.

Fontenla, J.M., Harder, J., Rottman, G., et al., The signature of solar activity in the infrared spectral irradiance, *Astrophys. J.*, 2004, vol. 605, no. 1, pp. L85–L88.

Hudson, H.S., Upper limits on the total radiated energy of solar flares, *Solar Phys.*, 1983, vol. 86, no. 1/2, pp. 123–130.

Hudson, H.S., Wolfson, C.J., and Metcalf, T.R., White-light frames: A TRACE/RHESSI overview, *Solar Phys.*, 2006, vol. 234, pp. 79–93. doi:10.1007/s11207-006-0056-y.

Imyanitov, I.M. and Chubarina, E.V., Elektrichestvo svobodnoi atmosfery (Electricity of a Free Atmosphere), Leningrad: Gidrometeoizdat, 1965.

Matveev, L.T., *Fizika atmosfery* (Physics of the Atmosphere), St. Petersburg: Gidrometeoizdat, 2000.

Maurya, R.A. and Ambastha, A., Transient magnetic and Doppler features related to the white-light flares in NOAA 10486, *Solar Phys.*, 2009, vol. 258, pp. 31–52. doi:10.1007/s11207-009-9397-7

Mikhailova, G.A., Mikhailov, Yu.M., Kapustina, O.V., Druzhin, G.I., and Smirnov, S.E., Power spectra of thermal tidal and planetary waves in the near-Earth atmosphere and in the ionospheric *D* region at Kamchatka, *Geomagn. Aeron.*, 2009, vol. 49, no. 5, pp. 610–623.

Neidig, D.F., The importance of solar white light flares, *Solar Phys.*, 1989, vol. 121, no. 1/2, pp. 261–269.

Nikiforova, N.N., Kleimenova, N.G., Kozyreva, O.V., Kubicki, M., and Mihnowski,?S., Unusual variations in the atmospheric electric field during the main phase of the strong magnetic storm of October 30, 2003, at Swider Polish midlatitude?observatory, *Geomagn. Aeron.*, 2005, vol. 45, no. 1, pp. 148–152.

Panasyuk, M.N., and 55 coauthors, Magnetic storms in October 2003, *Kosm. Issled.*, 2004, vol. 42, no. 5, pp. 509–554.

Paramonov, N.A., Studying the relation between solar activity and the electric field potential in the atmosphere according to the data of Soviet stations for 1957–1967, in *Atmosfernoe elektrichestvo* (Atmospheric Electricity), Leningrad: Gidrometeoizdat, 1969, no. 2, pp. 125–129.

Popov, I.B., Statistical estimates of the effect of different meteorological phenomena on the atmospheric electric potential gradient, in *Atmosfernoe elektrichestvo* (Atmospheric Electricity), St. Petersburg: Gidrometeoizdat, 2008, no. 558, pp. 152–161.

Pudovkin, M.I., Effect of solar activity on the state of the lower atmosphere and weather, *Soros. Obraz. Zh.*, 2006, no. 10, pp. 106–113.

RD 52.04.168-2001. Metodicheskie ukazaniya. Nablyudenie za elektricheskim polem (RD 52.04.168-2001. Methodical Instructions. Observation of the Electric Field), St. Petersburg: Gidrometeoizdat, 2002.

Roble, R.G., On solar–terrestrial relationships in atmospheric electricity, *J. Geophys. Res.*, 1985, vol. 90, no. D4, pp. 6000–6012.

Smirnov, S.E., Influence of a convective generator on the diurnal behavior of the electric?

field strength in the near-Earth atmosphere at Kamchatka, *Geomag. Aeron.*, 2013, vol. 53, no. 4, pp. 515–521.

Smirnov, S.E., Mikhailova, G.A., and Kapustina, O.V., Variations in the quasi-static electric field in the near-Earth's atmosphere during geomagnetic storms in November 2004 at Kamchatka, *Geomagn. Aeron.*, 2013, vol. 53, no. 4, pp. 502–514.

Tverskoy, P.N., *Atmosfernoe elektrichestvo* (Atmospheric Electricity), Leningrad: Gidrometeoizdat, 1949.

Veselovsky, I.S., and 52 coauthors, Solar and heliospheric phenomena in October–November 2003: Causes and effects, *Cosmic Res.*, 2004, vol. 42, no. 5, pp. 433–435.

Woods, T.N., Eparvier, F.G., Fontenla, J., et al., Solar irradiace variability during the October 2003 solar storm period, *Geophys. Res. Lett.*, 2004, vol. 31, p. L10802. doi:10.1029/2004GL019571.

Woods, T.N., Kopp, G., and Chamberlain, Ph.C., Contributions of the solar ultraviolet irradianñe to the total solar irradiance during large flares, *J. Geophys. Res.*, 2006, vol. 111A, p. 10S14. doi:10.1029/2005JA011507.

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SPELL: 1. irradiances, 2. actinometric