PECULIARITIES IN THE BEHAVIOR OF A HALO FROM ARTIFICIAL LIGHT SOURCES IN THE ATMOSPHERIC BOUNDARY LAYER

I.V. Samokhvalov and L.N. Popov

Tomsk State University
Received August 8, 1996

The experimental investigations of halos are being carried out at mid- and high latitudes. The investigations at mid-latitudes show, for the first time, that the light columns (halos) can have the shape of stationary strata. As was revealed for the first time, at high latitudes during magnetospheric substorms, the behavior of light columns is different in different regions.

In winter, under certain meteorological conditions the halo is observed from the ground artificial light sources in the form of a vertical light column. This phenomenon is known[1–4] but it is not investigated thoroughly. In this paper we describe the results of experimental studies of halos at mid-latitudes and high latitudes. The mid-latitude observations were in Tomsk, Kartaly of Chelyabinsk region, Krasnoyarsk (occasionally), Temirtau (occasionally), along the Alma-Ata–Djambul route; at high latitudes the investigations are carried out at Taimyr peninsula (Noril'sk, Talnakh, Kaierkan, Valek).

In the atmospheric boundary layer the halo occurs when the light is reflected from ice crystals (acicular crystals) floating in air and having the same orientation about vertical axis. In the author's opinion,[2] the appearance of light columns is due to light reflection from ice plates rotating fast around a horizontal axis.

It is strongly believed that the halo is observed in still air (in a meteorological sense) and low temperatures at severe cooling of the atmospheric boundary layer, when the process of water vapor sublimation takes place and ice crystals are formed.[3,5]

We know from our observations that the light columns (halos) from a ground light source are white in color, indicating that the halos of such a kind are due to the light reflection from the crystal faces.

The results of observations performed in Tomsk have shown that the halos from artificial light sources at mid-latitudes occur at temperatures from −13 to −20°C (Fig. 1). At the same time, all the literature available indicate that the halos occur at lower temperatures.

At mid-latitudes in the absence of geomagnetic storms the light columns from an artificial light source are stable, the dynamics of their behavior is determined by the variation of meteorological conditions. The height and brightness of light columns depends on the degree of ordering and density of ice crystals. The investigations, carried out in mid-latitudes, showed that the light columns may have the form of stationary strata (Fig. 2), i.e., alternating dark and bright sections that enables one to deal with the stratification of the atmospheric boundary layer.

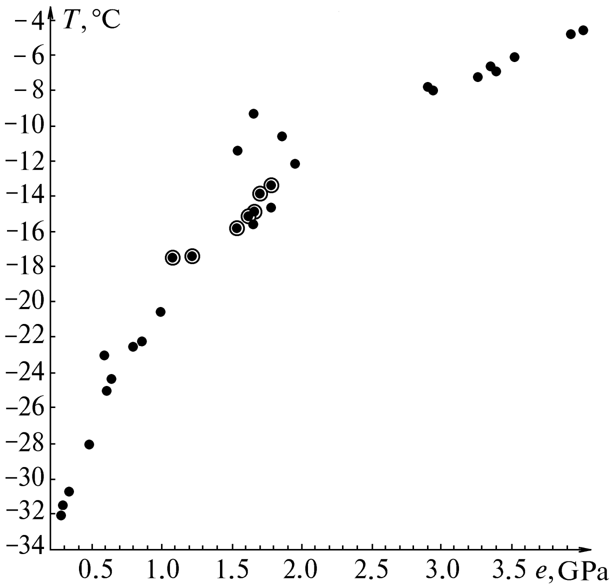

FIG. 1. The state of the atmospheric boundary layer during the investigations in the coordinates: temperature (°C) – humidity (water vapor partial pressure). The observations of halos from a ground source are denoted by dots.

The observations in high latitudes reveal that the light columns from artificial light sources appear at severe frosts that agrees with the data given in Ref. 3, where the ice crystals in the surface layer are considered to be formed as a result of water vapor sublimation at a deep air cooling. A considerable series observations obtained in Taimyr region (Noril'sk, Talnakh) show that 15–18 hours before the rise in temperature the light columns from artificial light sources (searchlights) disappear in spite of low temperature (−30°C; −35°C).

In high-latitudes in the absence of magnetospheric substorms the halos observed from

0235-6880/96/12 1043-03 $02.00

artificial light sources are also stable as in the case of mid-latitudes. During magnetospheric substorms, as it was first established, the behavior of light columns is different in different regions of high latitude area. As the experimental studies in Noril'sk region of Taimyr have shown, during the magnetospheric substorms the light column brightness varies with the period of 0.1 to 0.5 s.

FIG. 2. Photograph of stratified halos.

When the aurorae occur the variation of halo brightness occurs simultaneously with the variation of aurora brightness. The variations of the light column brightness are of a complex nature; in this case one can identify the following types of variations; namely, the variation of the light column brightness as a whole, the variation of brightness of a portion of the light column, the regime of running strata. This conclusion can be illustrated by the observational data.

Example 1. On November 19, 1989 we observed a bright light column (halo) from an artificial light source in Talnakh (Taimyr). The time of observation: 18:00–19:00 LT or 11:00–12:00 UT (GMT). The air temperature was −28.6°C. The light column is stable without variation of its brightness. Figure 3 shows the magnetogram, characterizing the level of magnetic field during the period under study.

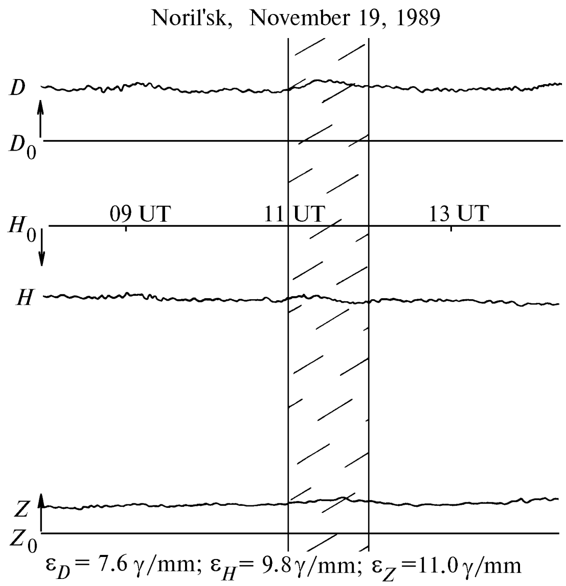

FIG. 3. The magnetic field intensity during the observation of a stable (unmodulated) halo; D and H are the horizontal and Z is the vertical components of the magnetic field intensity vector; $\varepsilon_{D,H,Z}$ are the absolute values of the field components in 1 mm *($7.95\cdot10^{-4}$ A/m). The time for observing halos* A/m *is denoted by the area shaded by vertical lines.*

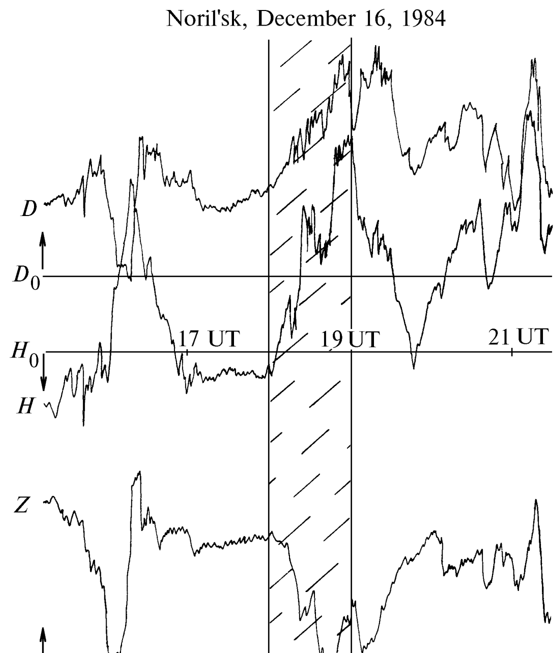

FIG. 4. The magnetogram, corresponding to the case of observation of the halos with modulated brightness. Designations are given in Fig. 3.

E x a m p l e 2. On December 17, 1984 in Noril'sk (Taimyr) during the period from 01:00 to 02:00 (LT) or at 18:00–19:00 (GMT) on December 16 the halos were observed from two searchlights illuminating the building site. Nearby along the azimuth a single aurora beam was observed. The halo intensity from artificial sources was modulated. In this case the halo intensity oscillations coincided in frequency with the aurora beam intensity variations. Moreover, the travels of altitude of bright areas in the halo and the aurora beam were observed practically simultaneously. Figure 4 gives the magnetogram, characterizing the magnetic field level during this period.

On the whole, a great bulk of data has been compiled on the light columns in Taimyr region as well as the magnetograms during the observation periods. In Tyumen' region the halo dynamics is also analogous to the aurora dynamics. In Yakutsk region the halos from artificial light sources during magnetospheric substorms are stable in their nature without modulation of their brightness.

It is quite probable that the variation of light column brightness is due to the presence of electric charge on ice needles (at irregular distribution of charge the needle becomes an electric dipole) and the interaction of the ice needle electric dipole with the atmospheric electric field, which, in its turn, is connected with the electrical conductivity of the Earth's underlying surface and ionospheric electric fields varying during the magnetospheric substorms. Regional peculiarities in the light column behavior can be due to the difference in electric characteristics of the underlying surface in different regions.

The halos from the ground light sources, observed in Taimyr, also carry prognostic meteorological peculiarities. For example, we have determined that 15–18 hours before the rise in temperature, followed by snowstorm, the halos from the ground light sources disappeared, even under stable frosty weather during the above-mentioned period at temperature from −30°C to −35°C.

A great bulk of observational data in Taimyr enabled us to reveal inhomogeneous spatial structure of occurrence probability of halos from artificial sources in the atmospheric boundary layer, that is indicative of the influence of local inhomogeneities of meteorological conditions or the crust.

REFERENCES

1. V.N. Obolenskii, *Meteorologiya* (Izdatel'stvo Geographicheskoi Literatury, Moscow–Leningrad, 1939), Part. 2, 371 pp.
2. M. Minnart, *Light and Color in Nature* [Translation from English] (Gos. Izdatel'stvo Fiz.-Mat. Literatury, 1958), 424 pp.
3. A.D. Zamorskii, *Atmospheric Phenomena* (Gidrometeoizdat, Leningrad, 1959), 96 pp.
4. N.N. Kalitin, *Optical Phenomena* (Izdatel'stvo Geographicheskoi Literatury, Leningrad, 1948), 451 pp.
5. P.D. Astapenko, *Problems of Weather* (Gidrometeoizdat, Leningrad, 1986), 392 pp.