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Thunderstorm Activity according to VLF Observations at Kamchatka

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Abstract—The azimuthal distribution of lightning discharges and cyclone epicenters at a distance of up to 4000 km from the observation point at Kamchatka is given. The azimuths of lightning discharges were determined using an ELF finder, and the cyclone epicenters were determined from meteorological maps. Time dependences of the distribution of received radiations from lightning discharges have been obtained.

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1. INTRODUCTION

Based on the observations of atmospheric noise in the ELF range in periods of tropical cyclone activity in the Pacific in August and October, 2002, it was shown that tropical cyclones are a strong source of internal gravity waves capable of penetrating to heights of 60–90 km of the lower ionosphere. The maximums in the power spectra of atmospheric radio noise are observed at periods of $T = 2$–3 h, and the intensity of radio noise is 1.5–2 times as much as the background level and changes significantly in the process of cyclone development. The fundamental component $T = 24$ h was distinguished in the spectral band $T = 0.5$–36 h, whereas the second and third harmonics are highly variable in the value of periods and intensity [Mikhailov et al., 2005]. However, the latter study did not consider the problems related to the seasonal dependence of the intensity of lightning discharges observed at Kamchatka. To determine this dependence, we compared thunderstorm activity observed by us with the epicenters of cyclone passing near Kamchatka.

The thunderstorm observations were performed using a direction finder developed at the Institute of Cosmophysical Research and Aeronomy of the Siberian Division of the Russian Academy of Sciences, which makes it possible to continuously register electromagnetic radiation, caused by lightning discharges (atmospherics), in the range of 3 to 60 kHz. The data, obtained from two magnetic and electric antennas, are processed in the real time and recorded on a digital data carrier [Druzhin et al., 2001].

2. AZIMUTHAL DISTRIBUTION OF LIGHTNING DISCHARGES AND CYCLONES

Figure 1 (at the top) shows the azimuthal distribution of lightning discharges (dots) and cyclone epicenters (squares) in the winter period (January, 2006). The signal from a lightning discharge was received under the condition when the threshold level of electric stress is exceeded by ~1 V m^{-1}. Each dot represents a single lightning discharge. To avoid filling the figure with extra points, we depict only each tenth lightning discharge. The general distribution of the number of lightning discharges (pulses per hour) is shown at the bottom of Fig. 1.

The azimuthal distribution of lightning discharges once per day includes cyclone epicenters located at a distance of up to 4000 km from Kamchatka. The cyclone epicenters were determined using the meteorological maps [http://www.imoc.co.jp/wxfax/asas.gif]. It is clear that the maximal intensity of light-

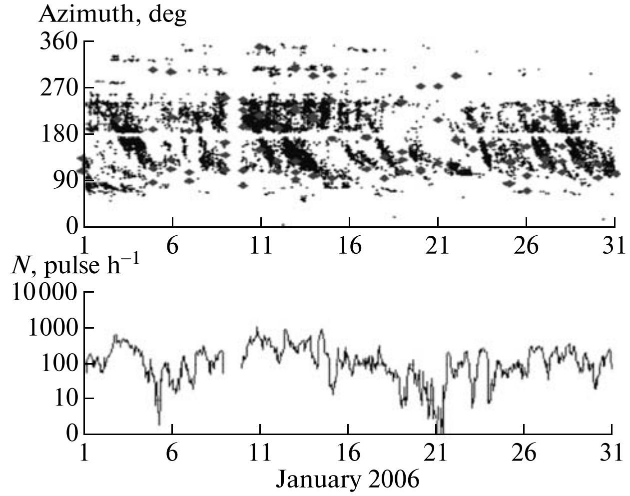

Fig. 1. Azimuthal distribution of atmospherics and cyclone epicenters (at the top) and the dependence of the number *N* of atmospherics (at the bottom) in the winter period.

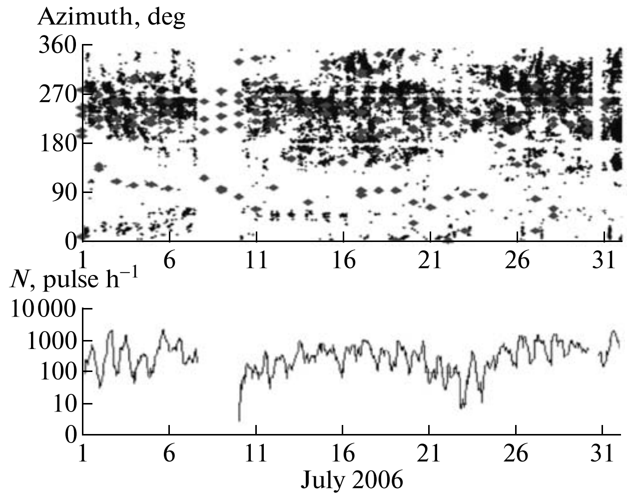

Fig. 2. Azimuthal distribution of atmospherics and cyclone epicenters (at the top) and the dependence of the number N of atmospherics (at the bottom) in the summer period.

ning discharges in January was observed in the range of azimuthal angles from 90° to 270°. The same range of azimuthal angles includes the largest number of cyclones, and intense thunderstorm activity originated in the west (in the vicinity of 270°), then shifted southward (180°), and ceased in the east (90°).

Because all cyclone epicenters (low- and high-power) located in the radius of 4000 km are mapped, it is difficult to trace the motion of each cyclone (their azimuthal location was determined once per day) and especially to relate individual cyclones to thunderstorm activity. However, based on a more detailed analysis of cyclone motions and thunderstorm activity performed earlier [Mikhailov et al., 2005; Cherneva and Druzhin, 2004], we obtained that high thunderstorm activity shifted synchronously with the motion of strong cyclones and typhoons originating southwest of Kamchatka in the Pacific region. We also noted that the intensity of lightning discharges in January 2006 strongly changed in time from several to several hundreds of pulses per hour, sometimes reaching 1000 pulse h^{-1}. The diurnal variations in the number of pulses were ill-defined and were observed on January 5, 6, 14, and 23 and were almost imperceptible on the remaining days.

Figure 2 indicates that summertime (July 2006) thunderstorm activity considerably increased and shifted northwestward. Evident shifts of individual thunderstorm sources (such as those observed in January) from west to east were absent. The most intense lightning discharges were observed in the west in the range of azimuthal angles from 180° to 360°. The hourly number of pulses in July increased as compared to such a number in January. The intensity of thunderstorms also considerably changed (10–2000 pulse h^{-1}). The number of cyclones was the largest in the southwest and west, where high thunderstorm activity was mainly observed. Cyclones were also observed in the east, where the thunderstorm intensity was low.

3. INFLUENCE OF CYCLONES ON THE ATMOSPHERIC ELECTRIC FIELD

We also studied the influence of Kamchatka cyclones on the vertical component of the atmospheric electric field (AEF). We established that the electric field strength decreases synchronously with the atmospheric pressure as a cyclone approaches the observation point [Kuznetsov et al., 2007]. We believe that this phenomenon is caused by the baric effect and the influence of radon emanation. Cyclones that approach the observation point lead to a decrease in the pressure and atmospheric electric field. The pressure reduction can lead to a radon emanation from the soil and, as a consequence, AEF reduction. The latter can also happen because cyclones can carry a large negative charge, which decreases the AEF value when approaching the observation point.

4. CONCLUSIONS

A comparison of the azimuthal distribution of lightning-induced electromagnetic emissions that came to Kamchatka with the distribution of cyclone epicenter indicated that the azimuthal distributions of thunderstorm and cyclonic activities mostly coincide. This indicates that observed thunderstorm activity largely depends on the intensity of cyclones passing through Kamchatka.

In winter, the largest number of lightning discharges was observed from the southwestern, southern, and southeastern directions and a very small number of cyclones came from northeast, north, and northwest. In summer, the azimuthal range of signals from thunderstorms extended, and intense emissions were also observed in the northwestern direction.

The emission intensity strongly depends on the time of day and cyclonic activity and can change from several to several thousands of pulses per hour. In the absence of high cyclonic activity, the maximal (minimum) number of atmospherics in the diurnal distribution is observed at night (in daytime). In the seasonal distribution, the maximal emission intensity was observed in summer.

Since thunderstorms are the important link in the process of energy transfer from the Sun to the Earth's surface, the obtained data can be used to study the solar–terrestrial coupling and predict thunderstorm activity.

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