Statistical analysis of the lightning type ground-to-cloud in the North Caucasus and the Stavropol territory

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Abstract. Statistical analysis of lightning activity in the North Caucasus and Stavropol Territory depending on orography is carried out. The statistical characteristics of ground-cloud lightning for the period 2009-2018 on the territory of 173056 km² were analyzed.

Introduction
Lightning pose a serious threat to the safety of human life and cause significant damage to the national economy. The greatest damage is caused by lightning earth–sky.

Lightning is a giant natural electric discharge in the atmosphere. It occurs due to the fact that an electric charge accumulates in a thundercloud. It is believed that the accumulation of charge is due to the crushing of raindrops ascending streams of warm air (which is why in winter there are almost no thunderstorms). Small droplets, carried up, acquire a negative charge, and larger — positive. As a result, between different parts of the cloud, as well as between the cloud and the earth, there is a huge tension of several tens or even hundreds of millions of volts, which is why lightning occurs [3].

This natural phenomenon is so dangerous not even by lightning, but by large hail, showers and strong wind, which in most cases are inseparable from the thunderstorm, since the phenomenon occurs in powerful cumulonimbus clouds [1, 4]. According to the characteristics of storm clouds, they can be divided into 4 types [5]:

• Single cell
  The phenomenon is weakly pronounced, barely noticeable.

• Multicellular cluster
  Thunderstorms, that occurs with this type of cloud, the most frequent. Have they not very great power.

• Multi-cell linear
  This type of cloud can boast of the presence of powerful gusts of wind accompanying the phenomenon. Although it is not particularly strong.

• Super-cell
  These are the most strong, rare and dangerous. Their main difference is the rotation of the air masses, which leads to the emergence of destructive tornadoes (tornadoes).

According to early estimates, the frequency of lightning strikes on Earth is 100 times per second. According to modern data obtained by satellites that can detect lightning in places where ground surveillance is not conducted, this frequency averages 44 ± 5 times per second, which corresponds to...
approximately 1.4 billion lightning bolts per year, 75% of these lightning strikes between clouds or inside clouds, and 25% — in the ground [5].

Often lightning, getting in the trees and transformer installation on rail, causing their ignition. Conventional lightning is dangerous for television and radio antennas located on the roofs of high-rise buildings, as well as for network equipment.

The complex relief of the territory of the North Caucasus in combination with the geographical location and features of the prevailing circulation processes here caused a fairly high thunderstorm activity on the territory [2].

The process of development of such lightning consists of several stages. At the first stage, in the zone where the electric field reaches a critical value, shock ionization begins, created at first by free charges, always available in a small amount in the air, which under the action of the electric field acquire significant speeds towards the earth and, colliding with the molecules that make up the air, ionize them.

To optimize lightning protection measures, it is useful to perform statistical analysis of lightning activity in the area to be protected.

The aim of this work is a statistical study of the earth-sky discharges in the North Caucasus and Stavropol region, within the range of the radar MRL-5 [6, 7], located in Mikhailovsk, Stavropol Region.

Figure 1. Orography of the area where studies of thunderstorm activity were carried out
In this paper, a statistical analysis of thunderstorm activity on the territory of 173056 km² was carried out, all discharges were recorded with the help of the ls800 lightning direction finding system, while the earth-sky discharges were divided into lightning fixation squares, and were equal to 500x500 meters. A special program developed for the study of thunderstorm processes [8] was carried out counting lightning discharges for the period from 2009 to 2018. Depending on the orography, all lightning discharges were divided into 5 groups by the coordinates of their detection, with the area of the studied orographic clusters is:

1) Lowland 0 to 200 meters, is 9.9%;
2) Elevations from 200 to 500 meters, is 18.9%;
3) Upland plateau from 500 m to 1 km, is 22.7%;
4) Low mountains from 1 km to 2 km 16290, is 26%;
5) High mountains more than 2 km 12517 km², amount 22.6 % of the total area of the study.

Statistical analysis of lightning discharge characteristics in the North Caucasus and Stavropol territory

From this graph it is seen that the number of thunderstorms recorded gruzopoluchatelej system includes protoplanetary located in the city of Stavropol, the city of Zelenokumske, at the site of Kyzburun, and in the Circassian varied from year to year. So the most quiet years were 2009, 2010, 2015 and 2017. At the same time, there is a clear tendency to increase the number of thunderstorms per square kilometer, depending on the height of the underlying surface.

![Graph showing number of lightning earth-sky per square kilometer for April-September, depending on the height of the underlying surface over the years.](image)

**Figure 2.** Number of lightning earth-sky per square kilometer for April-September, depending on the height of the underlying surface over the years

Analysis of the repeatability of discharges by year (Figure 2) showed that thunderstorms are more common on the plain and decrease with increasing height of the underlying surface.
Figure 3. Repeatability of lightning discharges of different intensity depending on the height of the underlying surface % averaged over the period (2009–2018)

The analysis showed that in the period from 2009 to 2018, in a radius of 208 km around Stavropol AWRC (i.e. square = 173055 km²) was observed 4395205 of the lightning discharge, like earth-the sky of these, 72% were negative and 28% positive. The majority of lightning strikes on the ground in the study area fall on the height of the lowlands 1000-2000 meters, and make up about 26% proportionally decreasing to 9.9% in the underlying surface (Figure 3).

Investigation of the number of lightning strikes per square area (Figure 4), for 2009-2018 showed that lightning twice as often hit on the plain than in the mountains.

Figure 4. Number of lightning discharges of the earth-sky type, per square kilometer, depending on the height of the underlying surface for the period 2009-2018
Monthly course of thunderstorm activity for the period 2009-2018, shown in Figure 5 showed that the most dangerous months are June and July, and less dangerous April and September.

![Figure 5. Monthly progress of the thunderstorm activity](image)

Data on the frequency of dangerous clouds are of great importance for aviation. As one of the parameters characterizing the degree of cloud hazard, the presence of lightning discharges is taken, the values of which correlate with the presence of turbulence, high air flow rates, intense precipitation, including the danger of meeting with hail.

Summary

The proposed method of statistical analysis of thunderstorm activity, implemented in the program and allow for automated analysis of extensive material, to study the features of the space-time distribution of various parameters of lightning discharges observed for many years.

For the emergence of thunderstorms requires two conditions: first, moist air, and secondly, convection air flow –this requires that the earth is thoroughly heated.

An important condition for the emergence of convection air flow–uneven heating of the air. This is created, in particular, the difference in height of different parts of the surface – even small hills increase convection.

Theoretically, thunderstorms would have to develop more intensively in mountainous areas, but studies have shown that thunderstorms are much more common on the plain. We can assume that this is due to the fact that the processes began to form in the mountains as the flow to the plain gaining speed and power, release the stored energy on the plain.

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