Analysis of lightning discharges activity within the territory of Buryatia in 2010-2016 based on WWLLN data

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Abstract. Thunderstorm activity is the main natural cause of forest fires. The development of new or modernization of existing systems for monitoring and forest fires forecasting requires the involvement of data on the spatial and temporal distribution of thunderstorms in monitorable forest areas. This article discusses the territory of the Republic of Buryatia (Russian Federation). The study of the spatial and temporal components of thunderstorm activity was carried out based on the World Wide Lightning Location Network (WWLLN) data. WWLLN data on thunderstorms locations for 2010-2016 were used. The network registers lightning discharges during the year. The thunderstorm season lasts from May to September. Archival WWLLN data for this period were selected. The resulting dataset allowed us to distinguish areas with different lightning activity. A high degree of spatial nonuniformity of thunderstorm activity in Buryatia was established. The number of lightning discharges begins to increase in May, the maximum is observed in July, and a recession occurs in August. Two daily maximum were revealed: the first maximum of number of lightning discharges is in the interval from 12 to o’clock and the second is about 19 o’clock of local time.

1. Introduction

Thunderstorm belongs to the category of natural hazards, the cloud-to-ground lightning discharge is a destructive factor. The thunderstorm is more dangerous when the discharge hits a person [1]. However, most often a cloud-to-ground discharge strikes trees, which leads to forest fires [2]. It should be noted that the share of forest fires by thunderstorms is noticeably less in comparison with fires caused by anthropogenic causes [3]. However, thunderstorm fires are characterized by a significant proportion of the territory covered by fire in a forested area. This is especially evident in areas remote from settlements and highways, as well as in mountainous areas [4].

Widespread use of forest fires forecasting is typical for the Canadian, American, and European systems [5-7]. The ISRM-Roslenshoy system of remote monitoring of forest fires was developed and put into operation in the Russian Federation [8]. All systems carry out a forecast of forest fires caused by thunderstorm activity. The spatial and temporal distribution of lightning discharges in the supervised areas is important for monitoring and forest fires forecasting [9].

There were no separate thunderstorm activity studies for the Republic of Buryatia. Such work was carried out for the whole territory of North Asia (40º-80ºN and 60º-180ºE) [10, 11], including Buryatia. As a result, lightning discharge density maps were created. As a source of information for
creating these maps, we used the World Wide Lightning Location Network (WWLLN) data for the summer seasons 2009-2010 and 2009-2014. The cartographic materials have a high degree of generalization, which leads to the relatively low spatial detailing in the regions of North Asia. From more detailed materials, we should note a lightning discharges density map, based on the Verey-MR RSLD data for the period 2003-2006 on the Altai-Sayan ecological region territory, including a part of the Republic of Buryatia [12]. The most accurate registration of lightning discharges by the RSLD ‘Verey-MR’ is carried out on the northern and north-eastern part of the republic. The Khamar-Daban and Little Khamar-Daban ranges are outside the Verey-MR RSLD control zone.

Thus, the analysis of the spatial and temporal distribution of lightning discharges in the Republic of Buryatia is an urgent task.

2. Objects, data and methods
We used WWLLN data [13, 14] for the period 2008-2016. The nearest to the city of Ulan-Ude five WWLLN stations are Gorno-Altaisk (≈1500 km), Yakutsk (≈1750 km), Beijing (≈1500 km), Lanzhou (≈1800 km) and Vladivostok (≈2050 km). The network registers lightning the whole year. The thunderstorm season lasts from May to September.

The atmospheric data recorded by WWLLN contain the following indicators: date, time, latitude, longitude, error and the number of stations in which the electromagnetic pulse was registered. Density maps of lightning discharges were calculated using the number of atmospherics registered by WWLLN over areas 10 × 10 km in size. The analysis of the daily and seasonal activity of lightning discharges was carried out. The registration time of a lightning discharge by the network WWLLN is made in accordance with the coordinated universal time. To estimate the daily course of lightning discharges, time was recalculated for each discharge in accordance with local solar time.

3. Results and discussion
The distribution of atmospheric density across the territory of the Republic of Buryatia is distinguished by spatial nonuniformity (figure 1). Most part of the territory of Buryatia is characterized by low density of thunderstorms. Against this background, the south-western part of the republic stands out, which coincides with the East Sayan and Khamar-Daban ranges (51°-53°N, 101°-105°E). In this region, the maximum atmospheric density is observed in the basin of the river Uri and in the upper Zun-Muren river. The average height of this territory is 1500 m, which increases to 2300 m in the axial parts of the ridges. To the east of Lake Baikal, the density of lightning discharges is very small. In this part of Buryatia, only in the northeast and southeast, the density reaches 0.2 discharges per square kilometer: in the northeastern part of the Vitim Plateau (55°N, 116°E), as well as in the estuary of the Chikoi river (right-bank tributary of the Selenga; 51°N, 107°E). The average height of this territory is about 1300 m above sea level, and the maximum heights are commensurate with the height of the Sayan ranges. In the basins of the northern part of Buryatia – the Upper Angara basin (56°N, 110°30'E), the Muya basin (56° 30'S, 115°E), the Barguzin basin (53° 30' 54° 30'N, 109°-111°E) and in other smaller basins, the density of lightning discharges is minimal.

A vast territory running to the east of Lake Baikal is of interest and perspective for the further study. Here, against low atmospheric density areas we identified fields where their density increases remarkably. These territories are coincided to heights of 1000-1500 m (on average), which corresponds to the mid-mountain relief. The configuration of regions with high and low atmospheric densities is also noteworthy. Mostly increased density areas are associated with isometric regions, and huge low density spaces are subordinated to the main orographic elements in this territory. In the orographic structure of the territory of Buryatia, the role of tectonic movements of different ages is significant, which gives reason to associate the atmospheric density distribution with the geological and tectonic features.
Figure 1. Lightning discharge density map in the Republic of Buryatia for the period from 2010 to 2016.

The obtained numerical estimates of the atmospheric density are in good agreement with the results of lightning activity research based on WWLLN data for 2009–2014, presented for the whole territory of North Asia (40º-80ºN and 60º-180ºE) [11] and for the territory of the Altai-Sayan region [15]. Currently, the effectiveness of regional networks is higher than global ones. This causes a lower atmospheric density, calculated on the basis of the WWLLN data, as compared with the Verey-MR RSLD, which works for FSFI (Federal State-Funded Institution) Aviation Forest Protection [12]. The northeastern part of the Republic of Buryatia is in the coverage area of the “Verey-MR” SRMR, which makes it possible to further compare the data of the two registration systems and adjust the WWLLN data for the southern and southwestern districts of the Republic of Buryatia, which are not included in the coverage area of “Verey-MR.”

An important factor in studying the conditions of thunderstorm formation leading to forest fire danger is not only the study of the places of the high lightning activity, but also the characteristics of the temporal course of thunderstorms. During the study period, years of decline and increase in the number of atmospherics are established (figure 2). The change in the number of atmospherics in some years can reach 40%. The maximum number of lightning discharges in 2014 is also characteristic for the territory of the Altai-Sayan region [15], and for Tomsk region which is situated to the north of the Republic of Buryatia [9].

The first thunderstorms on the territory of Buryatia may occur in April. The storm season ends in September. In autumn and winter, thunderstorm activity ceases (figure 3). The course of thunderstorm activity during the summer season corresponds to the trend identified earlier on the basis of meteorological data: the number of lightning discharges begins to increase in May, the maximum falls upon July, in August there is a decline in thunderstorm activity (figure 3). In September, the number of atmospherics is commensurate with their number in May. This trend is typical for average values over
the period.
For most of the years of the study period, the seasonal maximum of lightning activity occurs in July. However, there are years when the maximum shifts to June, e.g. in 2012, 2014, and to August in 2011. In 2015, the number of atmospherics in July has the maximum value for the whole observation period and it is 2 times higher than their average annual number in this month.

![Figure 2](image1.png)

**Figure 2.** Distribution of spherics of average density in May-September.

![Figure 3](image2.png)

**Figure 3.** Distribution of spherics within different months (average within the study period).

It was exactly in 2015 when the fire danger situation in Buryatia became aggravated in July due to the occurrence of natural fires by thunderstorms in remote areas. July accounted for 49% of the total number of discharges registered that year. At the end of the first decade and throughout the second decade of July, the greatest intensity of lightning discharges was observed. Perhaps it was those thunderstorms that led to the occurrence of wildfires.

The registration time of a lightning discharge is carried out by WWLLN according to the coordinated universal time. To estimate the daily course of lightning discharges, we performed the recalculation of time for each discharge according to the local solar time.

In the daily course of each year, two time periods are clearly distinguished: from 24 to 10 o'clock and from 11 to 23 o'clock (figure 4). The first segment is characterized by a minimum thunderstorm activity and a relatively uniform distribution of the number of discharges by the time of this range. The
second segment (from 11 to 23 o'clock) has a different distribution of the number of lightning discharges. During this time interval, there are two maximums in the number of lightning discharges: the first “lunch” maximum lasts from 12 to 16 o'clock and the second “evening” maximum takes place at about 19-20 o'clock. For the period 2010-2012, the second "evening" maximum exceeds the first "lunch" maximum. In other years, the largest number of lightning strikes was noted at the first lunchtime maximum.

![Figure 4](image)

**Figure 4.** The distribution of the atmospherics during the day (average over the study period).

### 4. Conclusion

The study showed that the WWLLN registers atmospherics throughout the entire territory of Buryatia, and the obtained data allow us to investigate lightning activity over a wide area, including remote areas. For this purpose, the atmospheric density indicator was used. In the course of the study, a high degree of spatial unevenness of thunderstorm activity in Buryatia was established, the causes of which may be associated with the geological and geophysical features of the study area. By analogy with previous studies [15], the authors found it rational to distinguish thunderstorm foci. As such, there may be southern and south-western regions, running to the East Sayan and Khamar-Daban ranges.

When studying the temporal distribution of lightning discharges, consistent patterns were identified which can be classified as fundamental: in the northern hemisphere the maximum thunderstorms occur in July, there are years when the thunderstorm maximum shifts to June or to August. Two maximums of lightning activity are distinguished during the day: the first “lunch” maximum at 12 o’clock and the second “evening” maximum at 19 o’clock.

Thus, the multilevel system of lightning registration is currently a real and high-demand monitoring tool. The global atmospheric registration system, for example, WWLLN, is capable of solving problems of the mesoscale level, and local systems, for example the Verey-MR RSLD, can solve more detailed tasks.

Evaluation of the participation of thunderstorms in the formation of forest fire in the territory of Buryatia as a whole and in areas with a high density of lightning discharges in particular is a task for the further research. Natural conditions in these areas often contribute to the spread of forest fires. In the mountains, due to a wide variety of forest fire situations, there are always areas in a state close to fire, which increases the probability of a fire during thunderstorms [12]. The results of these studies will be the basis for a detailed model of the forest fire danger forecast, being developed in Tomsk Polytechnic University.
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