DISTRIBUTION OF HAILSTORM AREAS IN KAKHETI REGION (GEORGIA) ACCORDING TO THE DIAMETER OF HAILSTONES IN THE CLOUDS

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Abstract

Hail causes great damage to the Kakheti region in Eastern Georgia. It partially or completely destroys agricultural crops: vineyards, orchards, annual and perennial crops. As a result, the country's economy suffers significant losses. The degree of damage largely depends on the diameter of the hailstone. The larger the diameter of the hailstone, the more damage the hail causes.

Based on the materials of the anti-hail service for 2016-2019, which includes data received from a radar station on the diameter of hailstones in the clouds, the height of conception, the processed points and time was studied the distribution of hailstorm areas in the territory of Kakheti region.

The results obtained will make it possible to analyze the climatic factors that cause damage to hailstorm areas, which will make a significant contribution to the development of methods for anti-hail work.

Keywords: *Hailstones, Meteorological phenomena, Climate, Natural disaster*

INTRODUCTION

Hail clouds originate in the cooled part of the clouds - above isotherm 0°C. In this zone, the growth of frozen water droplets and ice crystals in the embryonic state in the initial phase is carried out by condensation and sublimation, and later by gravitational coagulation. Their thickening to large sizes occurs at the level of a significant accumulation of water droplets, which is located at a height where the maximum velocity of the upward air flow in the vertical direction is observed (the middle of the clouds or slightly higher). The more the vertical air speed and cloud humidity increase, the more intense the size of the germinating hail grows. Both vertical velocity and cloud humidity depend on cloud strength, with increasing values for both elements increasing.

The size of hail largely depends on the heating of the earth's surface and, therefore, on the strength of convection. In addition, for hail the atmosphere itself must be unstable, more precisely, humid-unstable. Large hail usually falls in the summer, when the air temperature exceeds 20°C, sometimes 30°C. There are two reasons for this. First, large hail requires large vertical growth of the thundercloud, which occurs at high temperatures. Secondly, the 0°C isotherm should be as high as possible above the cloud base.

Hail most often occurs during the passage of a cold front [1-5] however, local orographic conditions caused by strong overheating of the land surface, as well as instability of the stratification of air masses, can enhance convective processes. Along with this, the aerosynoptic conditions of city-forming situations significantly depend on the geographical location and orographic features of the region. Aerosynoptic conditions for the arrival of large hailstones over a vast plain are formed when warm, moist air moves north over the land surface, on which a mass of relatively cold, dry air from the west accumulates from the mountains [6].

The probability of hail during the passage of a cold front in Georgia is 44%, with a wave disturbance in the south - 24%, and with internal mass convection processes - 17%. In the first two cases, hail processes usually cover large areas; in the third case, associated with convective processes, the hail area is not so large [2].

More than one work, including our co-authorship, has been devoted to the study of hail processes and the size of hailstones [7-14]. This paper presents the size distribution of hail grains in clouds in the Kakheti region according to corresponding radar data, which covers the period 2016-2019. The characteristics of the hail formation zone in clouds were studied, and the maximum heights in kilometres at which hailstones formed were determined. The number of zones treated by the anti-hail service in the municipalities of the Kakheti region was analyzed.

The completed work will contribute to more efficient anti-hail work in Kakheti and, accordingly, to a reduction in damage from hail.

STUDY AREA, MATERIALS AND METHODS

Study area

Kakheti region of Georgia and its individual municipalities: Sagarejo (Sag), Akhmeta (Akh), Kvareli (Kvar), Gurjaani (Gur), Telavi (Tel), Signagi (Sig), Lagodekhi (Lag) and Dedoplistskaro (Ded). Kakheti is the eastern border region of Georgia, bordering the Russian Federation in the north and Azerbaijan in the south. The total area of the region is 11309.5 km^2. There are 9 cities and 276 villages in the region, the administrative center is Telavi (41.75˚ north latitude, 45.72˚ east longitude).

Materials

Data of meteorological radar "METEOR735 CDP 10 - Doppler Weather Radar" of Anti-hail service of Georgia about the max diameter of hailstones D_o (mm) and the max height of the radio echo of hail clouds H_m (km) - radar products HAILSZ (Size) and MAX (dBZ) [15,16] - are used. Period of observation: April-October, 2016-2019. The area of shielded from the hail territory - 800000 hectares.

The work analyzes data on hail clouds with simultaneously measured values of H_m and D_o (≈ 600).

Methods

For the data analysis the standard statistical methods are used. The following designations of statistical information are used below: Mean – average values; Min – minimal values; Max - maximal values; St Dev - standard deviation; R^2 – coefficient of determination; R – coefficient of linear correlation; α – level of signification.

The degree of correlation was determined in accordance with [17]: very high correlation ($0.9 \le R \le 1.0$); high correlation ($0.7 \le R < 0.9$); moderate correlation ($0.5 \le R < 0.7$); low correlation ($0.3 \le R< 0.5$); negligible correlation ($0 \le R < 0.3$).

RESULTS

Table 1. The number of processed hail clouds and ranges of max hail cloud heights and max hailstone sizes in clouds in Kakheti.

Month	Number of processed hail clouds	Ranges of max cloud heights (H_m, km)	Ranges of max diameter of hailstone (D_o, mm)
IV	36	6-15	1.6-22.0
V	226	6-18	0.9-43.0
VI	174	5-15	0.9-48.3
VII	78	8-15	2.9-35.8
VIII	18	8-13	0.9-35.8
IX	68	8-18	2.0-63.1
X	2	14.5-16.4	35.8-63.1

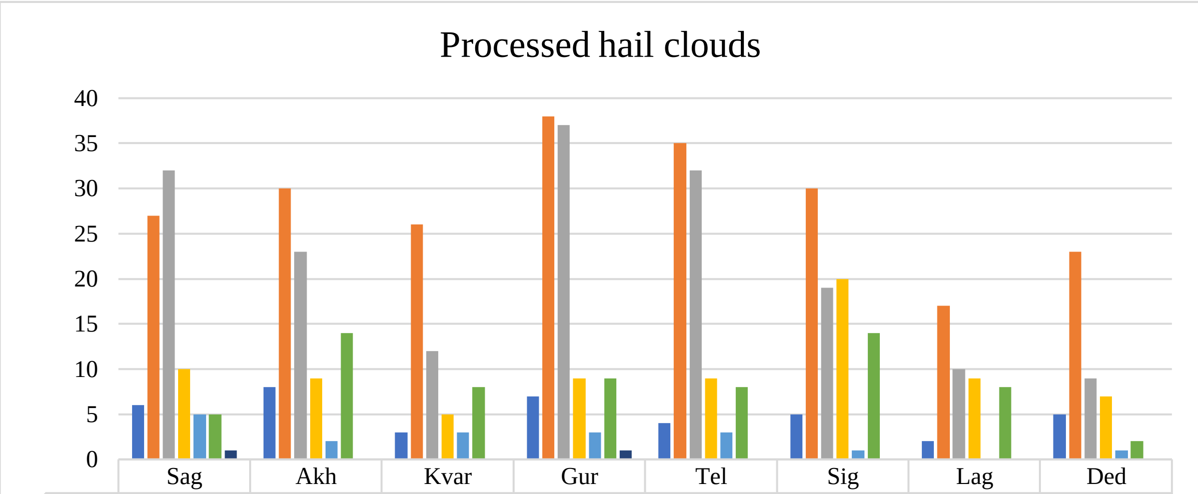
Table 1 provides general information on the number of processed clouds and ranges of max hail cloud heights and max hailstone sizes in clouds in Kakheti from April to October 2016-2019. In particular Table 1. shows that the max diameter of hailstones in the cloud during the study period was recorded in September (63.1 mm) and in April this parameter was only 22 mm. Also notable is the month of May, where hail clouds were processed 226 times by hail protection services over the four-year study period. The highest hail cloud height was recorded in May and September - 18 km each.

Although Kakheti as a whole is considered a hail-prone region, the incidence of hail clouds varies between municipalities.

In Figure 1 data on the number of zones processed by the anti-hail service according to municipalities from April to October, 2016-2019 are presented.

According to Figure 1 May and June stood out among other months in all municipalities during the study period. It was during these months that the anti-hail service processed the most hail clouds. The fewest hail cloud formations occurred in April and August (excluding October, where only 2 hail cloud formations were recorded over the four years).

For example, the number of hail clouds processed by the anti-hail service in May and June over the Gurjaani municipality were 38 and 37. The least processing of hail clouds is observed in the Lagodekhi municipality (maximum 17 cases in May).



	Sag	Akh	Kvar	Gur	Tel	Sig	Lag	Ded
IY	6	8	3	7	4	5	2	5
Y	27	30	26	38	35	30	17	23
YI	32	23	12	37	32	19	10	9
YII	10	9	5	9	9	20	9	7
YIII	5	2	3	3	3	1	0	1
IX	5	14	8	9	8	14	8	2
X	1	0	0	1	0	0	0	0

Figure 1. The number of zones processed by the anti-hail service according to municipalities (April-October, 2016-2019).

In Table 2 statistical characteristics of number of zones processed by the anti-hail service according to municipalities from April to September 2016-2019 are presented (October data has been omitted because only two hail clouds were recorded that month).

As follows from Table 2 the mean number of hail clouds change from 7.7 (Lagodekhi) to 17.2 (Gurgaani). Coefficient of linear correlation between number of hail clouds by municipalities changes from 0.72 (pair Sagarego-Signagi, high correlation) to 1.00 (pair Gurgaani-Telavi, very high correlation).

Table 2. Statistical characteristics of number of zones processed by the anti-hail service according to municipalities (April-September, 2016-2019).

Variable	Sag	Akh	Kvar	Gur	Tel	Sig	Lag	Ded
Mean	14.2	14.3	9.5	17.2	15.2	14.8	7.7	7.8
St Dev	12.1	10.4	8.8	15.9	14.4	10.6	6.1	8.0
	Correlation Matrix (R_{min} = 0.72, α=0.1)							
Sag	1	0.87	0.75	0.98	0.97	0.72	0.73	0.74
Akh	0.87	1	0.93	0.95	0.95	0.87	0.91	0.86
Kvar	0.75	0.93	1	0.86	0.88	0.84	0.90	0.93
Gur	0.98	0.95	0.86	1	1.00	0.78	0.81	0.81
Tel	0.97	0.95	0.88	1.00	1	0.81	0.84	0.84
Sig	0.72	0.87	0.84	0.78	0.81	1	0.99	0.84
Lag	0.73	0.91	0.90	0.81	0.84	0.99	1	0.86
Ded	0.74	0.86	0.93	0.81	0.84	0.84	0.86	1

Tables 3 and 4 show, respectively, the ranges of max sizes of hailstones in clouds and the max heights of the hail clouds for municipalities in the territory of Kakheti.

Table 3. Range of max diameter of hailstones in clouds (mm) by the Kakheti municipalities from April to October 2016-2019.

Processed zone	Month						
	IV	V	VI	VII	VIII	IX	X
Sagarejo	6.2-18.8	2.9-35.8	2.9-48.3	6.2-35.8	7.9-20.3	10.9-35.8	35.8
Akhmeta	1.6-17,3	0.9-25.5	2.0-35.8	6.2-35.8	6.2-17.3	6.2-48.3	0
Kvareli	4.7-17.3	0.9-25.5	10.9-35.8	17.3-35.8	0.9-9.8	4.7-35.8	0
Gurjaani	4.0-22	0.9-35.8	6.2-48.3	10.9-35.8	4.7-10.9	4.0-35.8	53.9
Telavi	4.7-10.9	0.9-35.8	6.2-40.5	10.9-35-8	12.0-25.5	10.9-43.0	0
Signagi	6.2-22.0	3.4-43.0	1.6-35.8	2.9-35.8	40.5	2.0-29.4	0
Lagodekhi	6.2-7.0	6.2-35.8	10.9-29.4	2.9-25.5	0	13.2-63.1	0
Dedoplistskaro	2.9-10.9	2.9-33.6	0.9-35.8	15.9-29.4	2,9	4.7-20.3	0

As can be seen from Table 3, in comparison with other months, May, June and September are characterized by the max size of hailstones in the clouds (43-48 mm); there was a case when the diameter of a hailstone in a cloud exceeded 63 mm (Lagodekhi).

Table 4. Range of max heights of hail clouds (km) by the Kakheti municipalities from April to October 2016-2019.

Processed zone	Month						
	IV	V	VI	VII	VIII	IX	X
Sagarejo	6-11	7-16	5-15	8-13	8-10	12-14	14.15
Akhmeta	7-13	7-18	8.4-15	8-14	9-13	10-15	0
Kvareli	9.7-12	7-16	9.5-14	8-12	9-12	11-15	0
Gurjaani	7-12	7-15	6.8-14	10-14	10-11	11-15	16.4
Telavi	10-13	6-15	7-15	10-15	8-12	10-17	0
Signagi	8-12	7-18	7-15	8-14	12	8-15	0
Lagodekhi	7	9.5-18	10-15	8-14	0	9.6-18	0
Dedoplistskaro	8.8-15	8-16	10-15	10-12	11	9-11.5	0

As can be seen from Table 4, the highest hail clouds are observed in May (H_m reaches 15-18 km) and September (H_m reaches 14-18 km); the lowest - over the municipality of Sagarejo (H_m = 5 km, June).

CONCLUSIONS

During the warm season in Kakheti, May, June and September differ in the size of hailstones in the clouds. During these months, hailstones reach their max size and often exceed 50 mm in diameter.

May and June also differ in the frequency of processing of hail clouds by the anti-hail service: May - 226 cases, June - 174 cases over the 4 years of the study (2016-2019).

The max height of the hail cloud processing zone in the territory of Kakheti ranges from 5-18 km.

The mean number of hail clouds change from 7.7 (Lagodekhi) to 17.2 (Gurgaani). Coefficient of linear correlation between number of hail clouds by municipalities changes from 0.72 (pair Sagarego-Signagi, high correlation) to 1.00 (pair Gurgaani-Telavi, very high correlation).

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