Movements of hail cells on the territory of the Kabardino-Balkarian Republic in 2017

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Abstract. The article is devoted to the analysis of the movement of powerful convective hail cells over the territory of the central part of the North Caucasus. The authors reviewed the studies carried out earlier in this area and analysed the results of the obtained works. The disadvantages of the previous studies are: use of materials, hail observations, meteorological stations and posts, and the fact they do not show the spatial distribution of hail cloud movements; for meteorological analysis, stations located up to 1000 m above sea level were used, which does not give us a complete picture of hail hazard. Now it is possible to study powerful convective clouds with the help of radar, which completely covers the territory of the study regardless of the inaccessibility. Also the software was used, which made it possible to create a database of radar characteristics of hail clouds.

1. Introduction

Long-term observations of hail clouds carried out in different geographical areas indicate the presence of certain patterns in the frequency of occurrence of these clouds. Hail clouds do not appear in arid areas, but do appear in the places where the air is warm and humid. It takes a lot of moisture (water vapor) to form a hail cloud. As it known warm air contains much more moisture than cold air despite of the same relative humidity. Hail clouds usually appear in the area of developed convection, where the speed of ascending air currents is maximal and may reach several meters per second. There are some mechanisms according to which the spatial separation of electric charges and the appearance of a strong electric field in a hail cloud are related to the presence of an ice phase in the cloud, and also to the presence of precipitation.

The hail clouds are observed almost over the country where the development of active convective processes is possible. The North Caucasus is one of the most hail-prone areas of the Russian Federation. The complexity of the orography, the high temperature of the underlying surface, and the high moisture content of the air masses from the Black Sea basin determine the development of intensive hail processes.

The aim of this work was to determine the movement of convective hail cells over the Kabardino-Balkarian Republic’s territory.

2. Research and discussion

The vertical extent and moisture content of a hail cloud is always greater than that of an ordinary (nonhail) cumulonimbus-rain cloud. So there are stronger upward air currents, throwing moisture to a higher altitude in a hail cloud. The main distinguishing feature of a hail cloud from any non-hail is the...
presence of lightning in it. That is why, the increasing of ascending currents in a hail cloud must be
directly or indirectly related to lightning. Lightning is the main air ionizer in a hail cloud. Because of
them, large amounts of ions are formed inside the hail cloud, which adhere to the aerosol particles.
Charged aerosol particles are active vapor condensation nuclei. Thanks to lightning, the hail cloud is a
generator of active vapor condensation nuclei. That is why, there are much more active nuclei in a hail
cloud, and therefore the process of water vapor condensation proceeds faster. Because of this, it has an
increased rate of latent heat release and increased upward air currents. As a result, a hail clouds forces
moist air from the surface layer of the atmosphere to a much higher altitude than a normal
cumulonimbus-rain cloud. As is known from radar observations, the maximum height of a hail cloud
can reach ~ 20 km [1].

In figure 1 you see a horizontal section of a hail cloud against the background of lightning
discharges. This figure is a superposition of the radar reflectivity and lightning detector readings.

![Figure 1](image)

**Figure 1.** Horizontal section of a hail cloud against the background of lightning discharges.

I have reviewed the previous studies in this area and analyzed the results. The disadvantages of
previous studies are: using the meteorological stations and posts in the observation of hail clouds -
they do not show the spatial distribution of the movement of the hail clouds; stations located up to
1000 m above sea level were used for meteorological analysis, but they does not give us a complete
picture of the hail hazard.

Only the use of radar in meteorology allowed us to obtain qualitatively new information - a general
picture of their spatial distribution over a large area at high spatial and temporal resolution. All data
obtained are based on radar information and lightning detector readings. As we can see in many
works, for example [2-5], a comparison of radar data with ground-based measurements gives quite
satisfactory results for practice.

The study was conducted with the help of an automated meteorological radar complex (AMRK)
«MeteoX» located at the Kyzburun Research Range. The basis of the complex is a two-wave
meteorological radar MRL-5. The AMRC «MeteoX» system offers the possibility of automatic
processing of the received information.
The radar allows making the location and movement of precipitation areas observations, and it can be used to obtain data on the intensity of precipitation within the radar range. Precipitation weakens the radar beam and this effect is most pronounced with shortwave radars. On the other hand, long-wave radar units do not detect weak precipitation as easily as short-wave radars do. We used a meteorological two-wave radar MRL-5, with wavelengths: =3.2 cm, =10 cm, its effective range is 130 km [2, 3].

60 convective cells of hail cells have been analyzed. In this paper, we consider individual hail cells of all known types of hail processes (single-cell, multicellular ordered, multicellular unordered, supercell, and transient-type processes) [6]. It is known that the supercell and most of the multicellular processes of the North Caucasus are formed in the mountain area, mainly in the interfluves of the upper Kuban and Malka rivers, on the border of Kabardino-Balkaria and Karachai-Cherkessia [6-8]. This fact is based on the results of research conducted in the 70-80 years of the last century. It is also noted there that the areas of the first radio echo's registration of hail cells vary from year to year. And the second maximum is usually located in the central area of Kabardino-Balkaria. The results of the analysis of radar data show that during the study period, most of the hail processes were formed in the interfluve of the Chegem and Cherek Balkarsky.

During the observation period from June to August 2017, 37 days with showers and hails were observed in the observation area. The development of hail clouds processes during the observation period was caused by the interaction of cold moist polar air masses with tropical air masses, the formation of cyclones and aggravation of frontal divisions, in the presence of meridional jet streams [9-12].

Based on the radar data, I constructed maps of the movement of hail clouds in the observation area (figure 2 and figure 3).

Figure 2. Movements of hail cells over the territory of the central part of the North Caucasus in June 2017.

The circled area on the maps shows the nucleation zone of the hail cloud, and the arrow points to the direction and location of dissipation. Most cases of hail were in the foothill areas of Zolsky, Baksansky, Chegmsky, Chereksky districts of the Kabardino-Balkarian Republic, as well as in the territory of the Republic of North Ossetia-Alania. There was almost no hail in the flat part of the republics in 2017. Next, I would like to give the distributions of the displacement of hail cells for the period of 2017, recorded in the central part of the North Caucasus (figure 4). The figure shows that the
predominant number of movements of hail clouds has a northeastern, eastern, and southeastern direction. The figure also shows that there is no movement of hail clouds in the northwest direction during the observation period, and there is only one case of movement in the west direction was recorded.

Figure 3. Movements of hail clouds over the territory of the central part of the North Caucasus in July and August 2017.

The area of cloud observations within the radius of view of the VGI radar station is located in the southern climatic zone of temperate latitudes. The formation of hail clouds occurs under the influence of global processes and local orographic features of the region. The activation of convective processes during the warm period of the year is mainly caused by two factors [9, 10]:

- the vicinity of the Black Sea, which lies in the path of the Western invasions, resulting in lower temperatures and increased moisture in the air;
- the influence of the Main Caucasus Range, which delays the movement of atmospheric fronts and contributes to their staging, wave formation and occluding.
3. Conclusion
In conclusion, it can be noted that the average seasonal number of days with hail processes decreases from northwest to southeast. During the warm season, a westerly-quarter air flow prevails over the North Caucasus, usually accompanied by the intrusion of polar and less often arctic air masses. As a result of the interaction of large-scale circulation with the terrain features of the North Caucasus regions, there are conditions that contribute to changes in the intensity of the background convective process. The central region, with the predominance of southwestern transport in the middle troposphere and northwestern transport in the lower troposphere, has the greatest amount of precipitation in the plains and foothills up to an altitude of 1000 m. It should be noted that the data obtained in the studies agree well with the data given by a number of authors [4, 5, 7]. Complementing the work done with new and previously obtained data, it is possible to more accurately determine the movements of hail clouds, which will make it possible to make recommendations for anti-hail services and agriculture.

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