

## WEATHER MODIFICATION IN GEORGIA: PAST, PRESENT, PROSPECTS FOR DEVELOPMENT

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**Summary:** Analysis of scientific and practical works on the artificial impact on the weather in Georgia in the past and at the present time (combating hailstorms, regulating the thunderstorm activity of clouds, artificial precipitation, etc.). The prospects for further development of these works are discussed.

**Key Words:** Weather modification, hail storm, artificial precipitation.

### Introduction

Scientific and practical works on the weather modification (increase and reduce rainfall, fight with the hail, fog disperse etc.) in many countries of world are carried out [1,2; <https://map.geoengineeringmonitor.org/>]. For an example, on fig. 1 depicts the map of the countries of the world, where were conducted in different years and are conducted similar works. As it follows from this figure, work on the weather modification is accomplished on all continents.

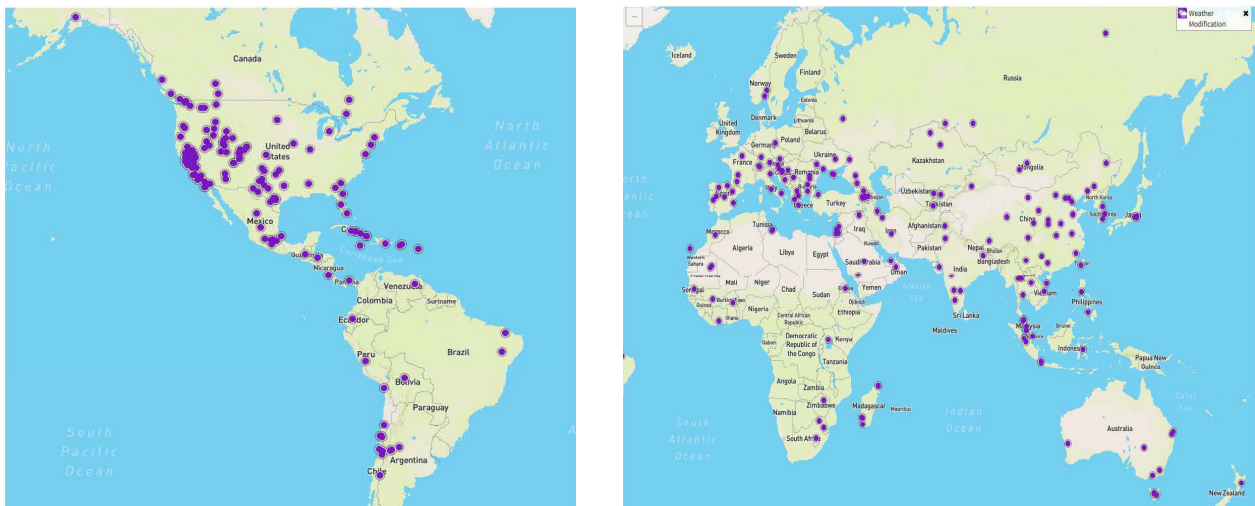


Fig. 1. Map of the countries with works on weather modification [<https://map.geoengineeringmonitor.org/>].

Currently, there are more than 50 nations operating hundreds of weather modification projects, particularly in arid and semi-arid regions all over the world. The lack of sufficient water resources limiting the ability to meet food, fibre, and energy demands and severe weather impacts are the primary motivation for these projects [[https://www.wmo.int/pages/prog/arep/wwrp/new/weathermod\\_new.html](https://www.wmo.int/pages/prog/arep/wwrp/new/weathermod_new.html)].

Protection from the hail is achieved almost in 50 countries of world over the total area of approximately 90 million hectares (Argentina, Austria, Bulgaria, Canada, China, Bosnia and Herzegovina, Germany, Greece, Macedonia, Moldova, Romania, Russian Federation, Serbia, Spain, etc.). In China anti-hail works are conducted in the territory of 42 million hectares. The countries weather modification system employs 47700 people, and has an arsenal including more than 7034 rocket launchers, more than 50 planes and nearly 6902 guns. In Russian Federation anti-hail works are conducted in the territory of 2.5 million hectares, etc. [2,3; [http://www.bjreview.com.cn/print/txt/2012-09/24/content\\_485733.htm](http://www.bjreview.com.cn/print/txt/2012-09/24/content_485733.htm)]. In Russian Federation in comparison with the Soviet period the physical effectiveness of anti-hail works grew on the average from 50-82 % to 82-92 % [2].

In Georgia in the beginning of the fifties of past century the institute of Geophysics of the Georgian Academy of Sciences began works on the fight with the hail. Later to these works was connected Transcaucasian Hydrometeorological institute. In 1967 for the realization of production works on the fight with the hail on the base of the Alazany anti-hail expedition of the institute of Geophysics the militarized service of fight with the hail in the former Soviet Union was for the first time created. As a whole, large-scale experimental, experimental-production and production work on action conducted in 1960-1990 in the regions of Kakheti and southern Georgia over the total area approximately 1.2 million hectare (Kakheti – 800 thousand hectare, southern Georgia – 400 thousand hectare) [2,4].

Positive effect changed in interval of 20 – 95% with mean value of 75 – 85%. Sometimes, when action was conducted to the super-power "super-cellular" clouds, effect proved to be zero, i.e., was noted strong hail damage. Almost in all works were used the crystallizing reagents (AgI, PbI<sub>2</sub>), in one region (southern Georgia) the action was conducted by the combined method (AgI, NaCl) [4,5].

Together with the works on the fight with the hail other work on the weather modification (artificial calling of a precipitation, regulation of thunderstorm activity of clouds, artificial descent of avalanches, etc.) to the Soviet period in Georgia within several decades were carried out. In these works rocket, plane, artillery and other methods of active impact on dangerous hydrometeorological processes were used [4,5]. In 1989 the specified works were stopped. In the next years the damage to national economy as a result of negative impact of the listed hydrometeorological processes significantly increased [6,7].

Taking into account this problem after 25 years of the interruption of the work of anti-hail service with the support of the government of Georgia, to the active operation of Scientific-Technical center "Delta", the collaborators of institute of geophysics and institute of hydrometeorology, the work of anti-hail service in Kakheti on 28 May 2015 was restored [5,8]. The description of the renovated anti-hail service in Kakheti and some suggestions on prospects for development of works on weather modification in Georgia is presented below.

## Results and discussion

### The renovated anti-hail service in Kakheti.

The scheme of the anti-hail service in Kakheti on fig. 2 and 3 are presented.

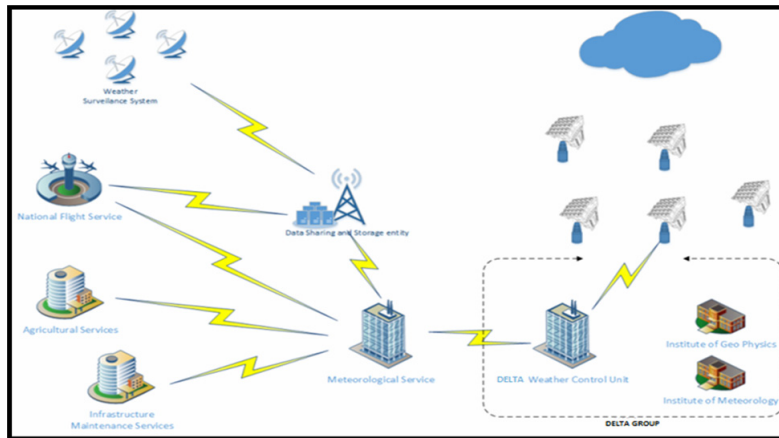
The restored Anti-hail system consists of [5, 8-11; <http://delta.gov.ge/en/product/anti-hail-system/>]:

1. Contemporary weather radar Meteor 735CDP10 of firm Selex ES with a special software.
2. Central control station with the change personnel.
3. Automatized fire control system.
4. 85 rocket launching sites.
5. The autonomous automated rocket launching device SD-26.
6. Anti-hail rockets (at present rockets "Loza-2" production of Bulgaria are used [12]).
7. Scientific group.
8. The group of the maintenance of radar.
9. The group of the maintenance of rocket guns.
10. IT group

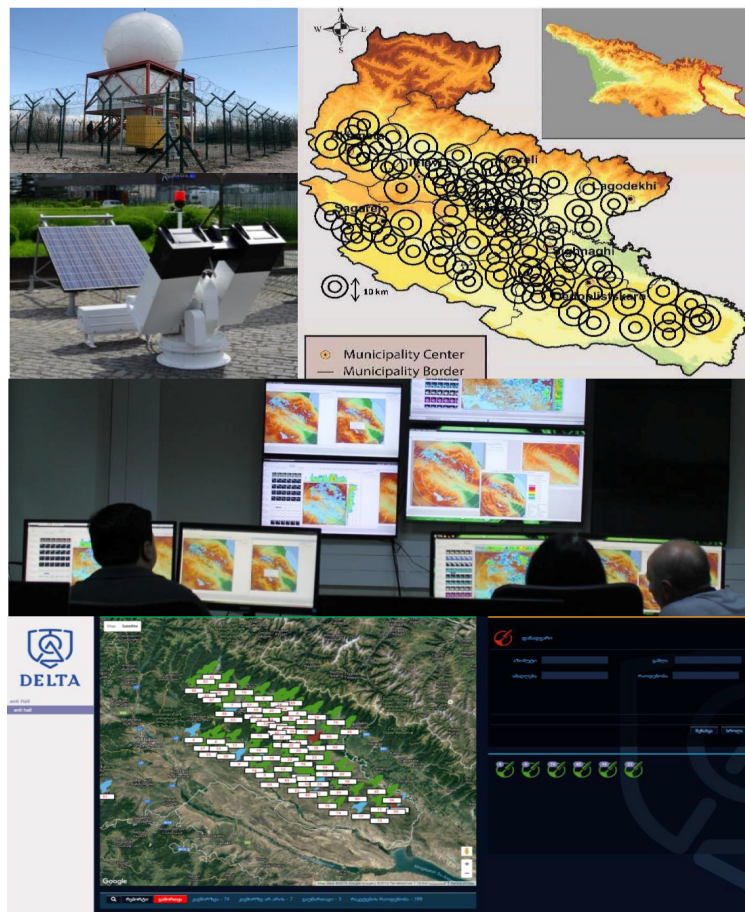
A group of media relations and also with air transportation service, various ministries, departments, municipalities, etc.

The weather radar is a C-band, dual polarized Doppler radar, which generates all the data to forecast hail-producing thunderstorms. All that information plus the databases of hail-consisting clouds used by the

software with the specific algorithms to generate the areas, where the silver iodide reagent is to be dispersed (fig.1). This radar placed in Eastern Georgia in the village Chotori on 1090 m height from sea level. Its actual area is 70-120 km, but working radius is more than 200 km with good data quality (fig. 2,3).



**Fig. 2. Scheme of the anti-hail service in Kakheti.**  
**The administrative centers of the municipalities of Kakheti: 1 – Akhmeta, 2 – Telavi, 3 – Kvareli, 4 – Lagodekhi, 5 – Gurjaani, 6 – Sagarejo, 7 – Signagi, 8 – Dedoplistskaro.**



**Fig. 3. Weather radar Meteor 735CDP10; Central control station; the autonomous automated rocket launching device SD-26; automatized fire control system for 85 rocket launching sites. Example of optimum areas of cloud seeding by the crystallizing reagent for the points of action by anti-hail rockets “Loza-2” in the protected territory in Kakheti. Height of the isotherm  $-6^{\circ}\text{C} = 4.4 \text{ km}$  [5, 8-11; <http://delta.gov.ge/en/product/anti-hail-system/>]**

The central control station is a dislocation place for the personnel, where all the information from weather radar and rocket launching sites are gathered, processed and where the automatized fire control system is. The automatized fire control system receives the data and the areas of seeding from the special software of weather radar, defines optimal launching site, the number of rockets needed and sends the orders to the proper launching devices (fig. 3). The central control station is located in Tbilisi (80 km from Chotori).

The radar monitoring of hail processes, analysis of meteorological situation in the region of action according to the data of radiosondes [http://ready.arl.noaa.gov/READYcmet.php, and also all other works on conducting of operations on the distance action on the clouds produces group of 4 operators (16 operators to 4 groups).

In the work of anti-hail service is provided the participation of the scientific organizations (institute of geophysics, institute of hydrometeorology, etc.), which must exercise scientific methods leadership of works, participate in the instruction of personnel, carry out the analysis of obtained data, improve the existing procedures of action on the atmospheric processes, develop new, etc.

To protect the whole region of Kakheti (800 thousand hectares), it is required to place 85 launching points – one in every 10 km, which is a working range of anti-hail rocket. There is a rocket launching device, solar panel, grounding and security systems installed on the launching site. The launching device carries 26 anti-hail rockets, aims to any given direction and fires (fig. 3). The launchers at the heights from 205 to 1775 m above sea level placed.

The physical (95 %) and economic (at least 28000000 GEL) effectiveness of anti-hail works in 2015 – 2019 were not worse than it was in 1967-1989 [13]. It is significant that if in the past in Kakheti personnel of anti-hail service comprised more than 800 people, at present this work it ensures only 33 people.

### Perspective of development of works on the weather modification in Georgia.

Natural disasters can be fought with both active methods (artificial impact on clouds and fogs, forced descent of avalanches, etc.) and passive means (various restraining engineering structures, disaster forecasting, etc.). Scheme for the development of works on weather modification in Georgia and related activities for active and passive prevention of some types natural disasters on fig. 4 is presented.



**Fig. 4. Scheme for the development of works on weather modification in Georgia and related activities for active and passive prevention of some types natural disasters.**

The next expansion the works in Georgia on weather modification is planned (Fig. 4).



**Acting polygon – Kakheti** (black points – rocket launchers). An increase in the number of missile points; installation of an additional radar covering the territory of Kakheti (Fig. 5); creation of an expanded network of meteorological stations for ground monitoring of the results of active impacts on hail processes and precipitation, etc.

**Planned polygons.**

**Kvemo Kartli** (yellow points – rocket launchers). In this region in the past century was polygon on the territories of municipalities Tetrtskaro, etc. [1,2,4,14]. In the environments of the territory of municipality Ninotsminda the work on an increase in the atmospheric precipitation was conducted.

**Shida Kartli** (blue points – rocket launchers). Polygon on the territory of municipalities Gori, etc. Planned period of the beginning of anti-hail works – 2019.

**Samtskhe-Javakheti** (green points – rocket launchers). Polygon on the territory municipalities Aspindza, Adigeni, Akhalkalaki etc.

**Mtskheta-Mtianeti** (red points – rocket launchers). Polygon on the territory of municipalities Mtskheta, Tianeti, etc. In the environments of the territory of municipality Tianeti previously the work on an increase in the atmospheric precipitation was conducted.

**Territory of the capital of Georgia – Tbilisi.** Work on active actions on atmospheric processes with the use of rocket technology for purposes of safety of population here are forbidden. It is possible the use of aircraft technology for the hail suppression and to the atmospheric precipitation regulation. It is also possibly the arrangement of rocket points on the boundaries of city for the action on the hail processes out of its territory.

**Ajara.** It is planned to organize work to reduce excess rainfall using ground (rocket, aerosol generators, etc.) and aircraft technologies.



Fig. 5. Estimated location of new

To improve the efficiency of weather modification works in Kakheti and their implementation in other regions of Georgia, it is planned to purchase several new meteorological radars. In particular, on the territory of eastern Georgia, it is planned to install 1-3 additional radars, which will be interfaced with the existing radar to Chotori. An approximate diagram of their location is presented in Fig. 5.

Is assumed the expansion of scientific studies on the development of new and the improvement of the existing active and passive methods of the prevention of natural catastrophes (hail, thunderstorm, shower precipitation, flood, the dust storms, fogs, landslides, avalanche, frosts, drought, forest fires, etc.). Renewal of the tests of different existing, improved and newly created ice-forming and hygroscopic reagents, and also other artificial aerosol formations for the active actions on the clouds and the fogs, fight with the frosts, the smog (pollution of atmospheric air) [15], etc. In near future the production of anti-hail

rockets with the improved ballistic characteristics is planned (increase in the effective radius of action, etc. [10, 2,16]).

In particular, in order to increase the efficiency of passive prevention of natural disasters, it is planned to build a regional model for the relationship of radar parameters with the above-mentioned dangerous hydrometeorological phenomena. This will allow for an early (several tens of minutes) warning of the population and relevant authorities about the upcoming dangerous hydrometeorological situation.

Examples of radar monitoring of hail processes, rainfall, and dust formation migration in eastern Georgia and its neighboring countries (Azerbaijan, Armenia) are presented in [5,17-20]. In the case of relevant interstate agreements, it is possible to organize an international service for short-term warning of the population and emergency structures about the possibility of dangerous meteorological phenomena.

## Conclusion

In connection with global changes (climate warming, an increase in the number of natural disasters), works on the weather modification is of particular relevance. In the last century, Georgia was one of the flagships of these works. After the restoration of the activities of the anti-hail service in Kakheti, which proved to be effective with minimal maintenance, there appeared prospects for further development of work on weather modification also in other regions of Georgia.

In the foreseeable future, it is planned to elaborate both active and passive methods of natural disasters preventing.

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