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Reconstruction of Anti-Hail System in Kakheti (Georgia)

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Abstract

Large-scale experimental, experimental-production and production work on action on hail processes in Georgia was conducted in 1960-1989 (Kakheti, Southern Georgia) over the total area of approximately 1.2 million hectares. Positive effect changed in interval of 20 - 95% with average value of 75 - 85%. In those following quarter of century, after the curtailment of these works, damage to agriculture from the hail grew and returned to the level, which was to the beginning of anti-hail works. In 2015 year in Kakheti over the area of approximately 650 thousand hectares the work on actions on hail processes were renewed. The description of the restored anti-hail system is given which includes: contemporary meteorological radar Meteor 735CDP10 of firm Selex ES; central remote-control station with the change personnel; the automated system of the fire control; 85 rocket launching sites; the autonomous automated rocket guns; anti-hail rockets; scientific group; the group of the maintenance of radar and rocket guns. The test probation of system showed the prospect of its further use for dealing with the hail. The physical and economic effectiveness of anti-hail works in 2015 year, in spite of the limited quantity of means of action (rockets), it was not worse than it is earlier in the years with the action. 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 30 people. Subsequently is assumed an increase in the shielded from the hail areas, and also, besides the anti-hail works, the use of radar for monitoring of dangerous hydrometeorological processes in eastern Georgia and adjacent to its territories of Armenia and Azerbaijan.

Key words:Weather modification, weather radar, anti-hail rockets, anti-hail system.

Introduction

To geophysical hazards belong: earthquakes, eruptions of volcanoes, landslides, mudflows, avalanches, mountain collapses; strong wind (storms, hurricanes, tornadoes, blizzards, etc.), intensive or long precipitation (rain, snow, hail), fogs, thunder-storms, high level of ultra-violet radiation, extreme air temperatures, droughts, etc.; floods, sea storms, typhoons, tsunami, intensive drift of ices, etc.; magnetic storms, falling of meteorites, cycles of solar activity, etc. [1,2].

Georgia - small mountain country with 15 climatic zones, in territory of which from time to time proceeds majority of the enumerated geophysical catastrophes. Therefore,

special attention was always paid and is paid to the study of dangerous geophysical phenomena in Georgia [3].

Concerning hail damages, Georgia is one of the hail-dangerous countries of world. Therefore to the problem of hail in this country are dedicated numerous works, that covers the wide spectrum of studies, beginning from the climatology of hail [4-10], ending with the mechanisms of its formation [11,12] and with the methods and the results of action on the hail processes [13-16].

Taking into account the significant economic damage, brought by hail damages, 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) [17,18].

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 [17, 18]. Almost in all works were used the crystallizing reagents (AgI, PbI_2), in one region (southern Georgia) the action was conducted by the combined method (AgI, NaCl).

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 [12, 17, 18]. 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 [17-20].

In contrast to Georgia in many countries of world the work on the weather modification in the last 25 years intensively was developed [21-28]. Considerably were improved the means of action on the clouds and the equipment for observation on convective clouds (meteorological radars), etc. [21, 23, 24, 25, 27]. Automatic systems for the action on the hail clouds are developed. All this made it possible to increase substantially the effectiveness of anti-hail works, etc. [21 - 23].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. [21, 28, 29]. 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 % [21].

In Georgia in the subsequent years after the end of anti-hail works special attention was given to the thorough analysis of the obtained earlier material about the hail damages both in the regions with the active actions on the atmospheric processes and as a whole for the territory of the Georgia. In particular, a whole series of works was dedicated to the climatology of hail and changeability of hail damages in the territory of this country [3, 5-10].

It was detected that the areas, beaten with hail in Kakheti increased in the years after the curtailment of anti-hail works and even they became more than prior to the beginning of the work of anti-hail service [30].

The empirical radar models of unicellular, multicellular and super-cellular convective cloud were created, the detailed maps of the distribution of the radar parameters of convective clouds above the territory of Kakheti were built [16]. The concept of interaction of aerosols with the convective clouds and the stimulations of the processes of the formation of the condensation and crystallization nuclei in them taking into account electrical, ionizing and other processes, which take place in the atmosphere and the clouds was proposed. It is assumed on the basis of concept that this interaction must be characterized by the regional special features, caused by both the physical conditions for the processes of forming the cloudiness, and by physical chemistry properties of aerosol-gas air pollution [12,31,32].

It was established that ionization of atmosphere by the natural and anthropogenic sources (radionuclides - radon, etc., cosmic radiation, the gamma emission of soil) plays the significant role in the formation of second aerosols in the atmosphere, including of the condensation nuclei, which have a great effect on the formation of the microphysical structure of clouds [32-34].

The evaluations of the influence of anthropogenic (including radioactive) pollution of the atmosphere on the intensity of thunderstorm and hail processes, and also the precipitation regime, showed that the relation of this pollution with the phenomena of the atmosphere indicated they have fairly complicated nature. However, as a whole the aerosol pollution of the atmosphere led to the intensification of the intensity of hail damages and, correspondingly, to the decrease of effectiveness in the anti-hail works [35-37].

The annual intensity of hail processes in Kakheti depends substantially on the aerosol pollution of atmosphere, although his dependence has fairly complicated nature. As a whole an increase in the nonradioactive aerosol pollution of atmosphere leads to the intensification of the intensity of hail damages and respectively to the decrease of the effectiveness of the action of anti-hail works. This effect appears also in daily variations in the intensity of hail processes. In Kakheti during the week-days the areas struck by hail, a logarithm of the multiplier of maximum radar reflectance, a quantity of liquid and solid precipitation are higher than into the weekends. Analogous situation also in the North Caucasus (mass, energy and a quantity of fallen hailstones during the week-days are higher than into the weekends). Increase in the fraction of the drop embryos of hail and decrease of the fraction of groats embryos (increase in the probability of an increase in the hail by the mechanism of warm rain) during the week-days in comparison with the weekends here occurs. In all likelihood in the period of the realization of anti-hail works in the former Soviet Union the effect of the anthropogenic pollution of atmosphere in the changeability of the intensity of hail processes bore regional nature. It is proposed while performing of work on active actions on atmospheric processes to consider the factor of anthropogenic air pollution [37].

In Kakheti (Georgia) and in the North Caucasus (Russia) in the period from 1968 through 1988 the effects of the decrease of effectiveness in the anti-hail works with an increase in the general aerosol pollution of the atmosphere were observed (Aerosol Optical Depth and the Turbidity Factor of the Atmosphere accordingly). In Kakheti this effect was mainly connected with the tendencies of an increase in the pollution of the atmosphere, and in the North Caucasus - with variations random components in the general aerosol pollution of the atmosphere [38].

On the serious influence of air pollution on the regime of precipitation in work [28] is noted also. It is shown, that anthropogenic aerosols might contribute significantly to the observed reduction of precipitation over northern China, and provide a possible feedback cycle of aerosol loading and precipitation that produces considerable harmful impacts on air

quality, the hydrological cycle, crops, and other environmental problems. Statistical analyses of historical precipitation and aerosols data have revealed that deeper precipitation clouds can be influenced by aerosols in the form of precipitation suppression. In particular, the suppression effect is stronger over mountainous areas than over plains, and the influence of anthropogenic aerosols on convective precipitation possibly plays an important role in summer over northern China.

Taking into account the importance of works on the artificial regulation of atmospheric processes in Georgia, including fight with the hail, before the government of the country repeatedly was raised the question in the need for the renewal of these works [17, 18]. Finally, in 2013 years preliminary decision about the restoration in Georgia of works on the weather modification was accepted, and first of all - anti-hail service in Kakheti. New development stage of scientific and practical searches in the region of the active action on the atmospheric processes in Georgia began from this point on.

Analytical studies of the contemporary methods of action on the convective processes, the organizational structure of the recreated service of fight with the hail taking into account new achievements in the region of active actions on the atmospheric processes were carried out [25, 26, 39-42].

Taking into account that the problem of the sharp shortage of specialists for weather modifications arose after 25 years of the interruption of the work of anti-hail service, it was decided with the aid of the Institute of geophysics with the support of Scientific-Technical center "Delta" within the brief periods to conduct training the corresponding personnel.

As a result, 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 [43]. The description of the renovated anti-hail service in Kakheti is presented below.

Results and discussion

The restored Anti-hail system consists of:

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 and SD-52.
6. Anti-hail rocket.
7. Scientific group.
8. The group of the maintenance of radar and rocket guns.

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 1090m height from sea level. Its actual area is 70-100 km, but working radius is more than 200 km with good data quality (fig. 2).

Fig. 1. Weather radar Meteor 735CDP10.

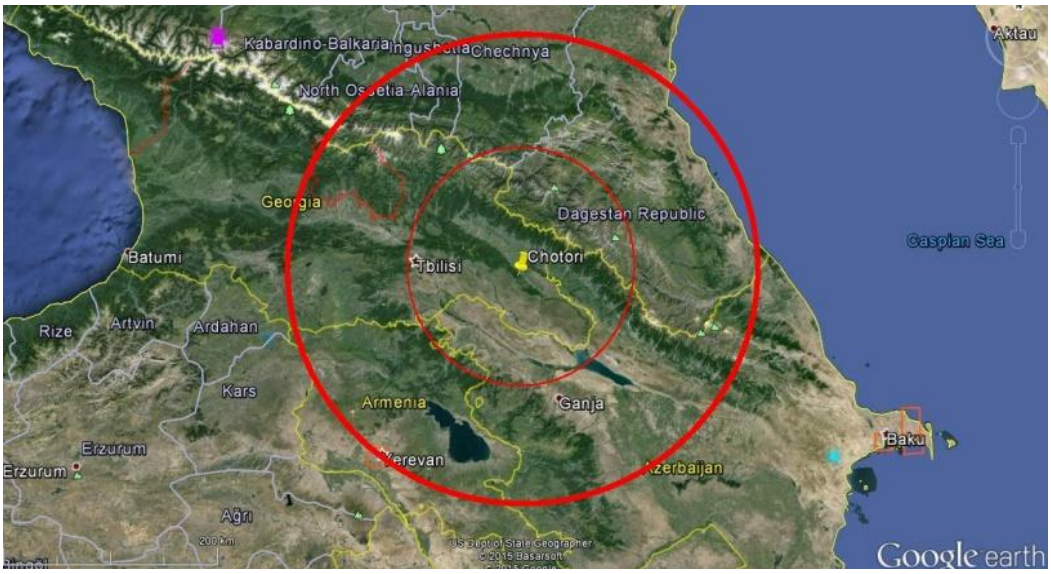

Fig. 2. Radar location in Kakheti.

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 [44], 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.

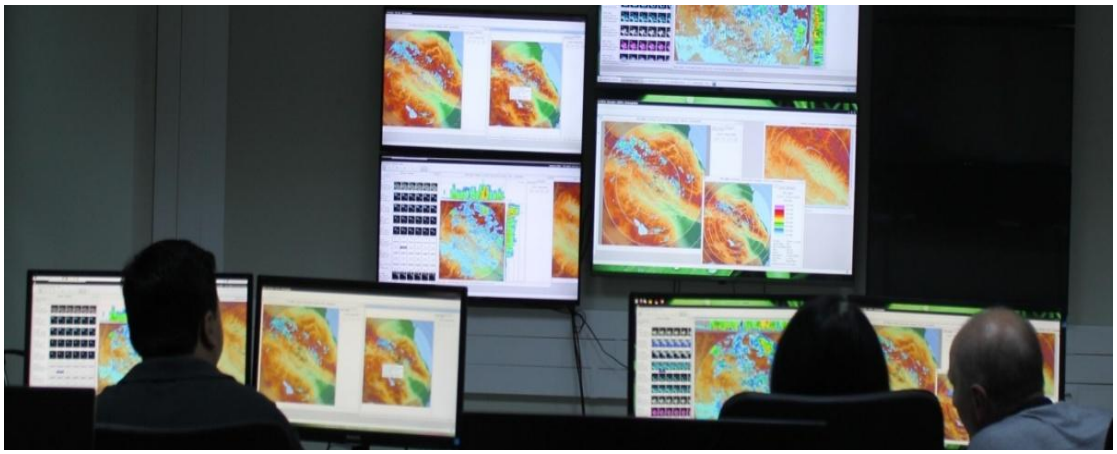

Fig. 3. The central control station.

To protect the whole region of Kakheti (650 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. 4).The launchers at the heights from 205 to 1775 m above sea level placed. In the range of heights from 205 to 375 m located 20 launchers, from 376 to 625 m - 37 launchers, from 626 to 875 m - 19 launchers, from 876 to 1125 m - 3 launchers and from 1275 to 1775 m - 3 launchers too [41].

Fig. 4. The autonomous automated launching device SD-26.

The anti-hail rocket SK-6 the production of Macedonia (fig. 5)is an unguided, 55 mm rocket, which carries 40 gram of silver iodide reagent and disperses it at an altitudes of 2.0 - 4.5 km, for 28-32 seconds [41,42]. Some parameters of anti-hail rocket SK-6 represented lower. The number of rockets needed during one year estimated to be 5000 units.

Fig. 5. Anti-hail rocket SK-6.

Anti-hail rocket SK-6 parameters.

- Rocket quantity in launching device SD-26 or SD-52: 26-52 rocket
- Elevation: 55-80°
- Traverse: 360°
- Rocket diameter: 55 mm
- Rocket weight: 3445 gram
- Rocket maximum velocity: 600 m/sec
- Shoot maximum distance (elevation 55°): 7200 meter
- The maximum from sea level (elevation 80°): 6000 meter
- The outlet of reagent from the rocket at a temperature -10°C – 1.28 10^6 particles

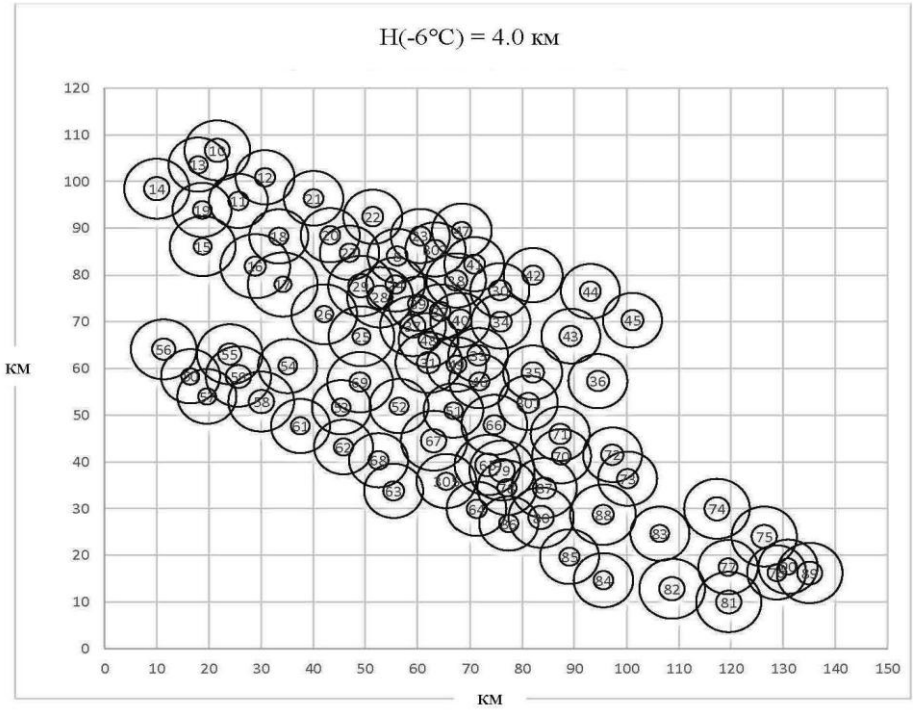

Fig. 6. Optimum areas of cloud seeding by the crystallizing reagent for the pointsof action by anti-hail rockets SK-6 in the protected territory in Kakheti. Height of the isotherm -6°C = 4.0 km. In the center of circle - number of the point of action.

Optimum areas of cloud seeding by the crystallizing reagent depend on the height of the arrangement of launchers and level of isotherm -6°C (fig. 6). As follows from fig. 6

distribution of the optimum areas of cloud seeding by reagent is unevenly. Basic reason for this - the insufficiently long courses of the rocket SK-6. Therefore, in near future the production of anti-hail rockets with the improved ballistic characteristics is planned (increase in the effective radius of action, etc.).

The special feature of the indicated launcher is the possibility of changing in quantity and diameter of containers (stems) for the anti-hail rockets, and the possibility of distance focusing on the angle of elevation and along the azimuth also of successive starting. Installation successfully underwent the first test probations. In 2015- 2016 it is planned to accomplish a production of the improved version of these installations taking into account the arrangement of an optimum quantity ofstems, protective housings for them from atmospheric precipitations, the improved program of the distance starting of rockets, etc. It is assumed also to create several mobile versions of launchers.

Finally in fig. 6-11 some examples of radar surveillance of the clouds are presented.

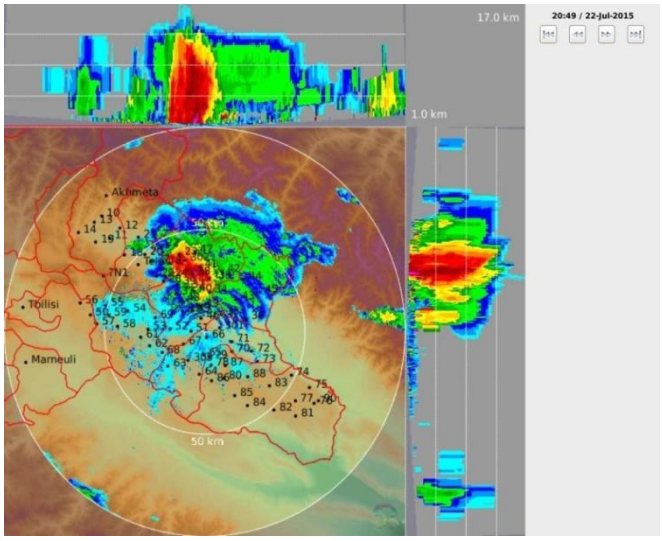

Fig. 6. Horizontal and vertical radar section of cloud 22.07.2015 in Kakheti in 20 hours of 49 min.

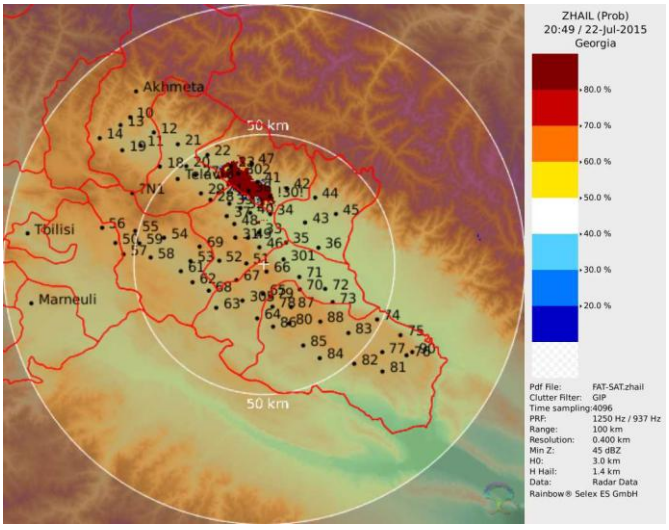

Fig. 7. Probability of hailstorm in cloud 22.07.2015 in Kakheti in 20 hours 49 min.

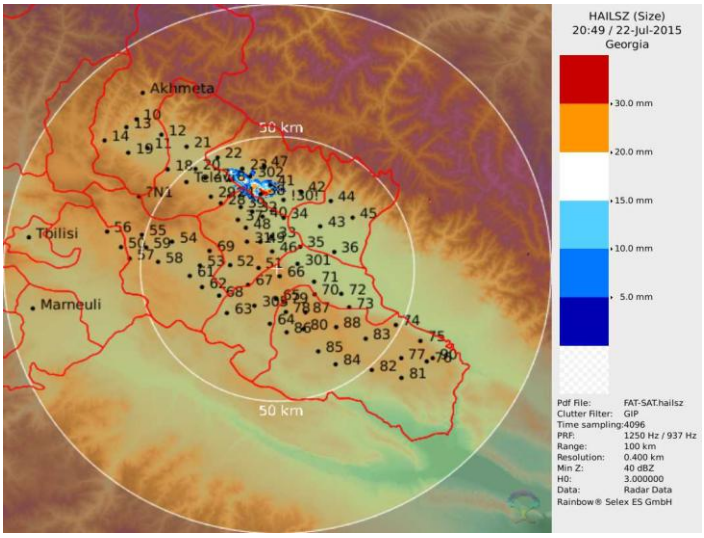

Fig. 8. Hailstones sizes in convective cloud 22.07.2015 in Kakheti in 20 hours of 49 min.

In fig. 6-8 fragments of radar surveillance of hail processes in Kakhetii (southeast from Telavi) 22.07.2015 20 hours of 49 min. are presented. As it follows from these figures, at the moment of observations the maximum altitude of hail cloud reached 17 km (fig. 6). The horizontal area of cloud with the probability of hailstorm of higher than 80% was approximately 50 km^2 (fig. 7). The horizontal area of cloud with the hailstones with the size more than 30 mm was approximately 2 km^2 (fig. 8).

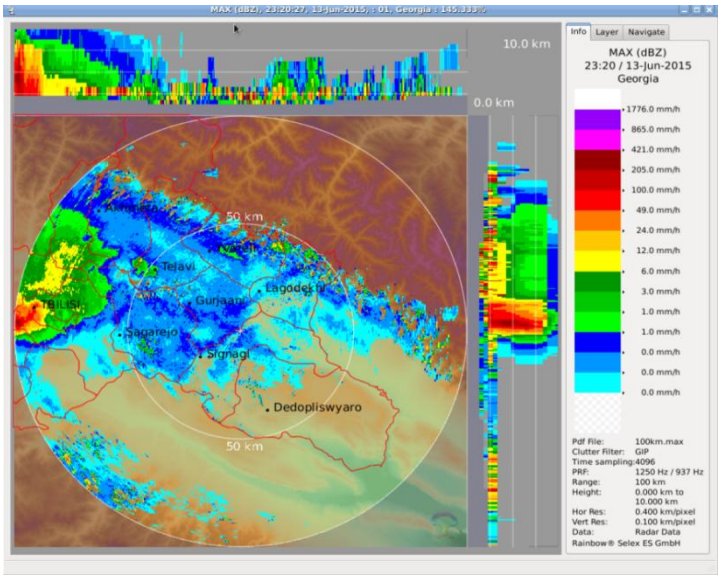

Fig. 9. Precipitation intensity from the thunderstorm cloud in the neighborhood of Akhaldaba 13.06.2015 in 23 hours 20 min.

In fig. 9-10 example of radar surveillance of the convective cloud in Akhaldaba region (southwest from the center section of Tbilisi) 13.06.2015 in 23 hours 20 min. depicts. As it follows from fig. 9, at the moment of observations the horizontal area of cloud with intensity of precipitation 50-100 mm/h was composed approximately 15 km^2, the horizontal area of cloud with intensity of precipitation more than 100-200 mm/h - 2 km^2.

For the clarity fig. 10 depicts 3D- picture of radar surveillance of this cloud. It should note, that during this day the cloud with the intensive rain and by thunderstorm was located on one and the same place of almost 5 hours. This led to the strong landslide, which overlapped river Vere, that flows in the direction to Tbilisi. The accumulated water subsequently broke through earthen mound, also, during several minutes one of the center sections of Tbilisi city, including zoo, they were flooded. Perished more than 20 people and a large quantity of animals. Essential damage was substituted to the infrastructure of city. Subsequently is provided the more detailed analysis of radar surveillance of the cloudiness and precipitation, which led indicated catastrophic event in Tbilisi.

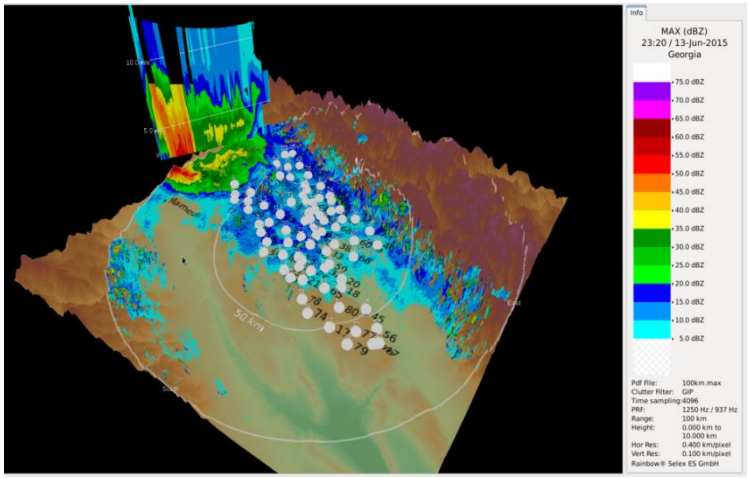

Fig. 10. 3D fragment of the radar picture of thunderstorm cloud in the neighborhood of Akhaldaba 13.06.2015 in 23 hours 20 min.

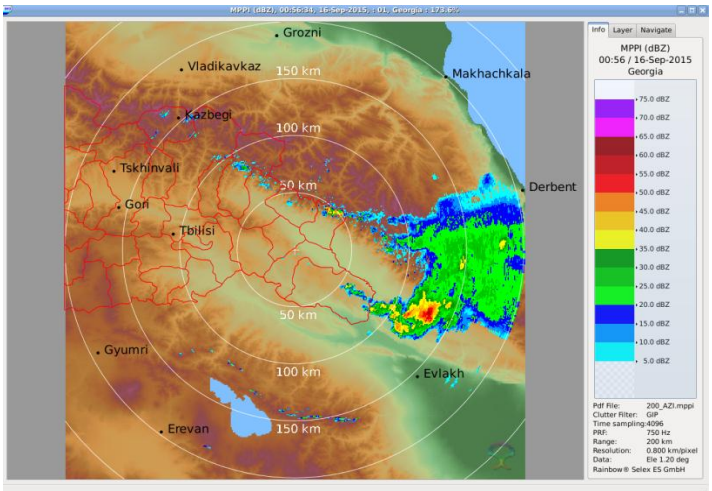

Fig. 11. Fragment of the radar picture of cloudiness above Azerbaijan 16.09.2105 in 0 hour 56 min.

Fig. 11 depicts example of radar surveillance of the cloudiness on the territory of Azerbaijan. As it follows from this figure, 16.09.2105 into 0 hour of 56 min. in 60 km north from Yevlakh city cloudiness with the horizontal area with the radar reflectance 50-60 dBZ of equal approximately 145 km^2 was observed.

Conclusions

After 25- years interruption in 2015 in Kakheti over the area of 650 thousand hectares of work on actions on hail processes were renewed. The contemporary anti-hail system of essential differs from that existed earlier in the Soviet period of time (contemporary meteorological radar and rocket launchers with remote control, etc.). Control of the processes of radar surveillance of the hail clouds in Kakheti and by rocket action on them is accomplished from Tbilisi. In the past in Kakheti the personnel of anti-hail service comprised more than 800 people, at present this work it ensures only 30 people. A constant improvement of methodological and technical components of anti-hail system is accomplished.

Subsequently is assumed an increase in the shielded from the hail areas, and also, besides the anti-hail works, the use of radar for monitoring of dangerous hydrometeorological processes in eastern Georgia and adjacent to its territories.

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სეტყვისსაწინააღმდეგო სისტემის აღდგენა კახეთში (საქართველო)

ა.ამირანაშვილი, ვ.ჩიხლაძე, უ.ძოძუაშვილი, ნ. ღლონტი, ი. საური

რეზიუმე

საქართველოში (კახეთი, სამხრეთი საქართველო) 1960 – 1989 წლებში 1.2 მილიონ ჰექტარის ფართობზე ტარდებოდა სეტყვის პროცესებზე ზემოქმედების მსხვილმასშტაბიანი საცდელი, საცდელ-საწარმოო და საწარმოო სამუშაოები. ზემოქმედების დადებითი ეფექტი იცვლებოდა 20 – 95% ის ინტერვალში საშუალო მნიშვნელობით 75 – 85 %. სამუშაოების შეწყვეტის შემდეგ სეტყვისგან მიყენებული ზარალი გაიზარდა და დაუბრუნდა იმ დონეს, რომელიც იყო ამ სამუშაოების დაწყების წინ.

2015 წელს კახეთში 650 ათას ჰექტარ ფართობზე სეტყვის პროცესებზე აქტიური ზემოქმედების სამუშაოები განახლდა. მოყვნილია აღდგენილი სეტყვისსაწინააღმდეგო სისტემის აღწერილობა, რომელიც თავის შემადგენლობაში მოიცავს გერმანული ფირმა Selex ES-ის Meteor 735CDP10 ტიპის თანამედროვე 5 სმ დიაპაზონის მეტეოროლოგიურ რადიოლოკატორს, დისტანციური მართვის ცენტრალურ პუნქტს, ცეცხლის მართვის ავტომატიზებულ სისტემას, 85 სარაკეტო გამშვებ პუნქტს, აღჭურვილს ავტონომიური ავტომატიზებული სარაკეტო გამშვები დანადგარებით, სეტყვასაწინააღმდეგო რაკეტებს და აგრეთვე პერსონალს, მათ შორის სამეცნიერო ჯგუფს, ლოკატორის და სარაკეტო გამშვები დანადგარების ტექნიკური მომსახურების ჯგუფებს.

სისტემის სატესტო გამოცდებმა უჩვენა სეტყვასთან ბრძოლის საკითხში მისი შემდგომი გამოყენების პერსპექტულობა. მიუხედავად ზემოქმედების საშუალებების (რაკეტების) სიმცირისა, 2015 წელს სეტყვასაწინააღმდეგო სამუშაოების ფიზიკური და ეკონომიური ეფექტურობა იყო არანაკლები, ვიდრე იმ წლებში, როდესაც ფუნქციონირებდა სეტყვასთან ბრძოლის სამსახური.

ნიშვნელოვანია ის გარემოებაც, რომ თუ საბჭოთა დროს კახეთში სეტყვასთან ბრძოლის სამსახურის პერსონალი შეადგენდა 800 კაცზე მეტს, დღეს ამ სამუშაოებს უზრუნველყოფს მხოლოდ 30 ადამიანი.

შემდგომში გათვალისწინებულია სეტყვისგან დასაცავი ტერიტორიების გაფართოება, და აგრეთვე, რადიოლოკატორის შესაძლებლობების გამოყენება აღმოსავლეთ საქართველოში და აგრეთვე აზერბაიჯანის და სომხეთის მიმდებარე ტერიტორიებზე საშიში ჰიდრომეტეოროლოგიური პროცესების მონიტორინგისათვის.

Восстановление противоградовой системы в Кахетии (Грузия)

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Резюме

Крупномасштабные опытные, опытно-производственные и производственные работы по воздействию на градовые процессы в Грузии проводились в 1960-1989 годах (Кахетия, Южная Грузия) на общей площади около 1.2 млн гектаров. Положительный эффект изменялся в интервале 20 - 95% со средним значением 75 - 85%. В последующие четверть века, после прекращения этих работ, ущерб сельскому хозяйству от града возрос и вернулся к уровню, бывшему до начала противоградовых работ.

В 2015 году в Кахетии на площади около 650 тысяч гектаров работы по воздействия на градовые процессы были возобновлены. Приводится описание восстановленной противоградовой системы, включающей: современный метеорологический радиолокатор Meteor 735CDP10 фирмы Selex ES; центральный пункт дистанционного управления со сменным персоналом; автоматизированную систему управления огнем; 85 ракетных пусковых площадок; автономные автоматизированные ракетные пусковые установки; противоградовые ракеты; научную группу; группу технического обслуживания радиолокатора и ракетных пусковых установок.

Тестовые испытания системы показали перспективность ее дальнейшего использования для борьбы с градом. Физическая и экономическая эффективность противоградовых работ в 2015 году, несмотря на ограниченное количество средств воздействия (ракет), была не хуже, чем ранее в годы с воздействием. Существенно, что если в прошлом в Кахетии персонал противоградовой службы составлял более 800 человек, в настоящее время эту работу обеспечивает всего 30 человек.

В дальнейшем предполагается увеличение защищаемых от града площадей, а также, помимо противоградовых работ, использование радиолокатора для мониторинга опасных гидро-метеорологических процессов в Восточной Грузии и прилегающих к ней территорий Армении и Азербайджана.