Methods of changing the thunderstorm electricity by modifying convective clouds natural and artificial origin

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Abstract. The report describes the methods of changing the thunderstorm electricity of convective clouds of natural origin, excluding the possibility of the formation of storm clouds, as well as methods of creating artificial clouds of vertical development, changing the electrical state of the atmosphere. Quantitative estimations of suitability to destruction of convective clouds over the Central and Northern regions of the European territory of Russia received as a result of processing of materials of aircraft sounding of the atmosphere of TAE-7,7 m on stations "Vnukovo" and Arkhangelsk are given. The results of field experiments on the creation of clouds of vertical development carried out to date are analyzed. Some fields of application of the methods of change of storm and atmospheric electricity given in the report are considered.

Introduction

Thunderstorm electricity is the main cause of thunderstorms, which are dangerous weather phenomena associated with convective clouds and can lead to significant damage and loss of human life [1]. The number of fires from thunderstorms in the world varies for different countries and their regions from 1 to 67%. In the US, lightning causes 6,000 to 10,000 fires. The share of forest fires from thunderstorms in Russia on average accounts for 10-15% of the total number of fires. It is noted that for some regions of the Russian Federation thunderstorm activity is almost the main culprit of vegetation fires. For example, in Priokhotye (Khabarovsk territory) from 1973 to 1996, thunderstorms caused an average of 16 fires per year, i.e. 375 fires (82.3 % of the total), and the fault of the person only 81 fire (17.7% of the total). In Siberia, up to 71% of thunderstorm forest fires in the Irtysh region are registered annually, up to 35-40% - in the Krasnoyarsk region [2].

According to the authors [3], electrical processes contribute to the appearance of clouds and other dangerous weather phenomena (wind gusts, tornadoes, hail). In view of the above, it seems relevant to conduct research related to the search for methods and means to change the degree of electrification of convective clouds.

Methods of modifying thunderstorm electricity

Currently, most scientists believe that the main mechanism of cloud electrification is the interaction of large and small ice particles [4-6]. This is especially true for the pre-storm stage of the cloud.

To change the size and number of large ice particles in the cloud, methods of influence based on the use of ice-forming reagents are used [1, 4, 7]. By regulating the amount of ice-forming reagent
introduced into the cloud, it is possible both to increase (accelerate) electrification and to suppress it (slow down).

Usually, the effects are divided into two large blocks – the mechanism of influence on the generation of electric charges of the cloud (1) and the mechanism of influence on the external target of the electric generator (2), which, in turn, are divided into 1.1 – 1.8 and 2.1 – 2.5 (see Figure 1) [3].

![Figure 1. Physical principles of the impact on the electrical state of convective clouds](image)

| 1. System of methods of influence on electric phenomena in clouds | 2. System of methods of influence on the external circuit of the electric generator |
|---------------------------------------------------------------|---------------------------------------------------------------------------------|
| on the mechanism of generation of an electric charge of a cloud | 2.1 Electrical losses cloud |
| on the parameters of microelectrical | 2.2 Conductive tips and ice-forming reagent |
| 1.1 Surfactants and ice-forming reagent | 2.3 Corona discharge on the earth, flows of ions from sources on the ground |
| 1.2 Acids, salts, alkalis | 2.4 Charged coarse powders and charged water drops |
| 1.3 Ice-forming reagent | 2.5 Metal cables, water columns after explosion, ion beams, electron beams, lasers |
| 1.4 Corona discharge on the earth, flows of ions from sources on the ground, the introduction of charged particles | 1.5 Meteotron |
| 1.6 Initiation of downward movements | 1.7 Destruction of the ordered structure of air flows |
| 1.8 Charged coarse powders and charged water drops |

Analysis of existing and currently proposed methods of influence on the electrical processes in the clouds leads to the conclusion that in practice it is advisable to use methods based on the creation of downward movements in the clouds in order to destroy them. According to modern concepts [3, 8], the use of downward movements in the cloud is achieved by:
- discharge of coarse powders (e.g. cement);
- the use of jet aircraft in the mode of kupirovaniya;
- applications of heavy-duty parachutes;
- creation of directed explosions;
- causing precipitation to create a downward flow.

In practice, the method based on the discharge of coarse powders (cement) is mainly used. The practice of full-scale experiments on the destruction of convective clouds by dumping packages of cement at the top of them showed that it is possible to achieve a positive effect at a vertical length of the cloud layer of no more than 4 km. Taking into account this fact, in this work as a result of
processing the materials of aircraft sounding of the TAE atmosphere-7.7 m at Vnukovo and St. Petersburg stations for 1953-1964. Quantitative estimations of convective clouds suitability to influence for the purpose of their destruction in months of the warm half-year (April-September) are given. Only processed about 9,000 (8873) lifts the planes-MW sounders. These data are presented in figures 2, 3.

![Figure 2. Repeatability of convective clouds suitable for destruction over the Central region of the European territory of Russia](image)

![Figure 3. Repeatability of convective clouds suitable for destruction over the Northern region of European territory of Russia](image)

Since the impact on convective clouds in this case it is advisable to carry out the method of discharge of bulk materials (for example, cement), neither the temperature nor the phase structure of the cloud in this case were not taken into account.

The estimates of the frequency of convective clouds suitable for destruction over the Central region of the European territory of Russia given in Fig. 2 show that the most common conditions for exposure to clouds are observed in April (68%).

In July, there are fewer such clouds – 40%. In General, in the warm half of the year the frequency of suitable for scattering convective clouds is slightly more than 50%.

As for the assessment of the suitability of convective clouds for destruction over the Northern region of the European territory of Russia, we can note the following. According to the data shown in Fig. 3, in the warm period of the year, the frequency of convective clouds suitable for destruction in all
months (April-September) is almost 100% (99%). Such high values of estimates of the frequency of convective clouds suitable for destruction are due to the fact that over the Northern region of the European territory of Russia clouds with a capacity of more than 4 km are quite rare (observed) due to the location of the area under consideration.

The above methods of changing the electric state of convective clouds belong to the already formed cloud formations. However, in [3] (Figure 1, item 1.5) indicates that the changes of state of atmospheric electricity can be achieved also through the creation of artificial convective clouds when using meteotron.

The meteotron is a technical device that allows to create artificial upward vertical air movements in the atmosphere. The rising air cools, and at some height its temperature reaches the dew point. Thus, conditions are created for condensation of water vapor into water droplets or sublimation into ice crystals in the presence of condensation or freezing nuclei. In the end, all these processes can lead to the formation of a convective cloud.

The first meteotron was built in 1961 by A. Dessen in France, at the Center for atmospheric research [9, 10] and included approximately 100 burners, each of which received oil at high pressure in an amount of 10 to 15 l/min. The power of the installation was approximately 600 – 1000 thousand watts [11].

A more powerful installation for initiating upward air flows in the atmosphere was created in the late 70-ies at the Institute of Geology and Geophysics of the Siberian branch of the USSR Academy of Sciences (Novikova S. I. meteotron). The meteotron provided for the use of 120 jet burners, which allowed to obtain a power of about 10 million kW, which is an order of magnitude more than the power of the dessin meteotron.

Overall a significant drawback of the above meteotron is incomplete fuel combustion, which is accompanied by release of large amounts of soot, significantly pollute the atmosphere.

To eliminate air pollution at the Institute of applied Geophysics, it was proposed to burn fuel not in burners, but with the help of turbojet engines. Two models of such installations were created: one on the basis of four rd-3M turbojet engines, the second on the basis of ten somewhat more advanced RD-3M-500 engines.

Field experiments with the installations of this Institute, conducted during the summer of 1966 in Riga in conditions of cloudless weather showed that by the end of the series of experiments began with the development of natural Cumulus clouds, usually in the area of the coast away from the installation [11].

The analysis of functioning of stationary meteotron has led to the conclusion that for work that requires a large fuel consumption, the result is not always obvious. The use of meteotron Institute of applied Geophysics, is associated with serious difficulties caused by the disassembly-assembly and transportation.

Taking into account the above, it is proposed to use a heat engine, which is an aircraft turbojet engine mounted on the chassis of a vehicle, as a meteotron to create convective clouds [12]. As an example, Figure 4 shows the appearance of a special heat engine – TMS-65. A feature of this installation is the ability to control the engine nozzle in a vertical plane.
The creation of convective clouds is achieved by introducing into the nozzle of the engine an aqueous solution of hygroscopic substances (calcium chloride, carbamide, ammonium nitrate, table salt, etc.) of a certain concentration or aqueous solutions of mixtures of these substances of a certain concentration. Full-scale experiments on the creation of fogs, wavy and convective clouds using the above chemical and technical means were carried out in different seasons and in different regions of the Russian Federation [12]. As an example, Figure 5 shows fragments of an experiment to create convective clouds in the Central region of the European territory of Russia.

Figure 4. A heat engine TMS-65 on truck chassis Ural-375D

Figure 5.1 Photo experiment in the creation of convective clouds

Figure 5.2. Photo experiment in the creation of convective clouds
The created convective cloud quickly grew into a powerful Cumulus cloud, which was facilitated by favorable meteorological conditions (low condensation level to which the jet with the reagent coming out of the engine nozzle, weak wind (1-3 m/s), high relative humidity (85-90%), the absence of an inversion layer in the boundary layer). After 1-2 hours, the cloud reached the shape of a cumulonimbus cloud, which undoubtedly can indicate a change in the level of atmospheric (thunderstorm) electricity.

Summary
The paper proposes the main practical methods of changing the electric state of convective clouds, based on the creation of downward movements in the cloud by dumping packages with coarse powders (eg, cement), as well as the creation of artificial convective clouds using a special heat machine (eg, TMS-65), dispersing aqueous solutions of hygroscopic reagents.

In the first case, the impact on natural clouds of vertical development is carried out in order to exclude the possibility of the growth of convective clouds (in particular, powerful cumulonimbus) in cumulonimbus (hail, thunderstorm), which can be a source of lightning that can lead to fires.

In the second case, on the contrary, there are real possibilities of changing the state of atmospheric electricity in the direction of its increase, up to thunderstorm. Technically, today it is already quite feasible. Areas of practical use of this direction require special justification and research.

References
[1] Koloskov B P, Korneev V P, Shchukin G G 2012 Methods and means of modification of clouds, precipitation and fogs (SPb.: RSHU).
[2] Dmitriev A N, Krechetova S Yu, Kocheeva N A 2011 Thunderstorms and forest fires from thunderstorms in the Republic of Altai: monograph (Gorno-Altaysk: RIO Gaga).
[3] Mikhailovsky Yu P, Sinkevich A A 2017 On methods of active effects on electrical phenomena in clouds (Reports of the all-Russian conference on cloud physics and active effects on hydrometeorological processes, 23-27 October 2017 Part 2. Nalchik. Ufa: AETERNA) 197-205.
[4] Zimin B I 1978 Regulation of the development of thunderstorm activity of convective clouds under the influence of ice-forming aerosols (Proceedings of CAO) 136 104.
[5] Imyanitov I M, Nikandrov V Ya 1965 About the possible impact on the electrical processes in the clouds // In: collection of Short texts and abstracts of the conference on active influences on the electrical processes in the clouds (L.: Ed. GGO) 138-142.
[6] Imyanitov I M, Kulik M M, Chuvaev A P 1957 Preliminary data on experiments on regulating the development and change of the electric state of powerful convection clouds in the southern regions of the European territory of the USSR and Transcaucasia (Proceedings of the GGO) 67 33-58.
[7] Kachurin L G 1990 Physical bases of influence on atmospheric processes (L.: Gidrometeoizdat).
[8] Doronin A P 2014 Effects on atmospheric phenomena and processes (SPb.: VKA named after A. F. Mozhaisky).
[9] Dessens A 1969 Can we change the climate? (L.: Gidrometeoizdat).
[10] Dessens H, Dessens J 1964 Experience avec le meteotron an Centre de Recherehes atmospheriques (J. Rech. Atm.) 1 158-162.
[11] N. And ... Wulfson, Levin L M 1987 Meteotron as a means of influence on the atmosphere (M.: Moscow branch of Gidrometeoizdat).
[12] Doronin A P, Kuleshov Yu V, Petrochenko V M, Shchukin G G 2017 Artificial clouds and fogs as a promising means of solving economic and environmental problems (Reports of the all-Russian conference on cloud physics and active effects on hydrometeorological processes, 23-27 October 2017 Part 2. Nalchik. Ufa: AETERNA) 141-149.