Prospects for using mobile launching sites in hail suppression operations

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Abstract. The paper describes the reasons underlying the development of the concept of mobile launching sites for hail suppression operations. The main disadvantages of using fixed launching sites in hail protection network at the present time are enumerated. Possible variants of the method of using mobile launching sites are proposed. The main tactical and technical characteristics of the mobile launching site are given.

1. Introduction
When analyzing the causes of hail damage in target areas of all hail suppression services, we come up against situations where the main factors of hail damage are the insufficient location density of launching sites (LSs) or the insufficient pre-target area in this given confine of the protected area. The difference with other more common causes of hail damage, such as incorrect selection of seeding areas, insufficient seeding coverage, late detection or identification of the seeding target, etc. that can be rectified in the future without material expenses, is that the hail suppression services, as a rule, have not any possibility to dislocate LSs from position to position or build additional LSs in the pre-target area due to financial and organizational reasons. Thus, from year to year we have to accept the inappropriate LSs location that is often the cause of the insufficiency of pre-target area or LSs density.

The paper proposes an approach to solving the problem of the unsuitable LS locations in the target area, consisting in the development of the concept of mobile launching sites (MLSs) for hail suppression operations. The rationale of this concept is that, other things being equal, the same area can be protected by a smaller number of LSs, if it is possible to ensure the permanent adaptation of the LSs location chart to the changing external factors.

2. Research methodology
When developing the concept of a MLS, it is necessary to analyze the weak points of the existing location chart of the fixed LSs, as well as the reasons for arrangement of their locations.

More than half a century has passed since the beginning of hail suppression activities on the territory of the Russian Federation. The first hail suppression means were the artillery shells «Elbrus» stuffed with glaciogenic agent and fired from anti-aircraft guns KS-19. Until now, the location chart of most of the LSs in the North Caucasus and Krasnodar hail suppression services is arranged according to the trajectory characteristics of those shells. That technology allowed the pinpoint seeding of the cloud that often did not comply with the technology requirements related to seeding speed.

Afterward, stepwise over time, the anti-hail rocket complexes began to be incorporated into the hail protection network that significantly increased the rate of agent injection into the cloud. It was
achieved through the use of linear seeding by «Alazan» anti-hail rockets and quasi-volumetric seeding by «Kristall» rockets.

Besides the above mentioned anti-hail rockets, since the beginning of hail suppression activities, other rocket systems were developed, each having, as a rule, its own trajectory parameters. The trajectory characteristics of the most well-known anti-hail rockets are shown in the table 1.

| Rocket     | Smoke generator starting time, (s) | Smoke generator stopping time, (s) | Range to smoke generator start point, $R$ (m) | Range to smoke generator stop point, $R$ (m) | Distance between nearby LSs in the row, $L$ (m) | Distance between LS rows, $D$ (m) |
|------------|------------------------------------|-----------------------------------|----------------------------------------------|---------------------------------------------|------------------------------------------|---------------------------------|
| Alazan-2M  | 7                                  | 40                                | 2000                                         | 8000                                        | 6500                                      | 14620                           |
| Nebo       | 7                                  | 59                                | 3000                                         | 13000                                       | 10000                                     | 24000                           |
| Oblako M   | 7                                  | 50                                | 3000                                         | 8000                                        | 5000                                      | 15197                           |
| Kristall-1 | 3                                  | 40                                | 1000                                         | 12000                                       | 11000                                     | 21330                           |
| Kristall-2 | 12                                 | 52                                | 2000                                         | 12000                                       | 10000                                     | 21817                           |
| Alazan-6   | 13                                 | 43                                | 4000                                         | 10000                                       | 6000                                      | 19079                           |
| Alazan-9   | 15                                 | 50                                | 4000                                         | 11000                                       | 7000                                      | 20857                           |

Description of the ideal chart of LS locations is given in [1], where the entire target area is the 100% beaten zone, figure 1. In fact, this location chart is never realized due to a variety of technical, financial and organizational reasons, but it can be used as a visual aid for illustration of the influence of rocket trajectory characteristics on the distance between launching sites.

![Figure 1. LS locations with full overlap.](image)
Legend: $r$ – distance from a launcher to the beginning of the seeding track; $R$ – distance from a launcher to the end of the seeding track; $L$ – distance between LSs in the row; distance between rows.

As follows from figure 1, to ensure the complete overlap, the distance between nearby LSs in a row must be equal to:

$$L = R - r,$$

and the distance between the rows must be equal to:

$$D = \sqrt{3 \cdot R^2 + 2 \cdot R \cdot r - r^2}.$$

The values of these variables for various types of anti-hail rockets are listed in the columns 6 and 7 of the table 1.

Such LS locations, when being fixed, are insufficiently dense for some anti-hail rockets and excessively dense for others, as follows from the values given in the columns 6 and 7 of the table 1. Suppose, for example, that the figure 1 shows the LS protection zones when using the anti-hail rockets «Kristall-2», and then the protection zones for the case of using «Alazan-2», on the scale of figure 1, will look like this, figure 2.

![Figure 2. LS locations without full overlap.](image-url)

As it follows from figure 2, when using other types of anti-hail rockets with significantly different trajectory characteristics and without changing the previous LS locations, there may be a lot of dead zones in the target area, which is undesirable and may be the cause of hail damage.
When planning the fixed LS locations on an area where the hail suppression activities were not being carried out before, as a rule, there is no reliable information about the most common places of hail genesis or directions of hail cloud displacement. This is because in order to have such information, it is necessary to conduct radar observations of the hail clouds development and displacement in a given area within a number of years, but this is never done in practice. Thus, when planning the locations of fixed LSs, the project developers are guided only by very approximate general considerations about the aerological situation in a given area. This initial uncertainty is superimposed with the factor of climate changes over time. These changes have become most evident in recent years in the regions of the Russian Federation, where the hail suppression activities are being carried out.

Hail suppression activities in the Soviet period were being carried out on target areas with strictly fixed boundaries. Presently, there are frequent cases of changes in the boundaries of the target areas, depending on the hail suppression service contractual obligations to private and business customers. In view of this, some of the launching sites remain unused for a time, while others are overburdened with work.

Recently, in some regions of the Russian Federation, the techniques to enhance precipitation are being developed, using as a mean of seeding agent delivery to clouds not an airplane, but a rocket. For these purposes, either anti-hail rockets with conventional AgI seeding agent or anti-hail rockets with other types of agents are used. The problem is that there are, as a rule, no shortage of precipitation in areas where the hail suppression activities are being carried out, and there are a low probability of hail hazards occurrence in arid climate areas, this is why there are no infrastructure for cloud seeding activities there. The use of a universal platform in the form of mobile launching site (MLS) would allow to solve this contradiction and to use the same infrastructure for both hail suppression and precipitation enhancement whenever required.

Presently, methods of mathematical modeling are widely used to improve the technology of hail suppression. The results of such modeling should indicate the most promising ways to improve the hail suppression technologies. Today there are developed models needing verification in practice. The problem is that only hail suppression services possess infrastructure for cloud seeding operations. These services provide hail protection according to the technology set forth in guidance documents and cannot deviate from them to scientific experiments. When having mobile launching sites, this problem can be solved by selecting one or few launching sites and displacing them out of target area for performing the required experiments in the radar coverage zone, but outside the target area, ensuring with that the integrity of the experiment.

3. Results and discussion

It is most logical to determine the basic tactical and technical requirements for mobile launching site (MLS), proceeding from the intended method of their use. At this stage, the method will be formulated in its simplified form for their use in two basic cases:

- MLS use in an area where the hail suppression activities were not being carried out before;
- MLS use in an area where the hail suppression activities are being carried out now by mean of fixed LSs.

When using MLSs in an area where the hail suppression activities were not being carried out before, their initial locations are determined according to the location chart of fixed LSs given in [2]. With the course of time (approximately once every 5 - 10 years), when accumulating the statistical information on the characteristics of hail suppression operations and the areas of the most frequent hail cell origination, trajectories of their displacement and location of hailfall areas, it will be necessary to redefine the MLS locations according to the method described in [3] and redeploy them. During annual campaign, the MLS remain, as a rule, in the same position. The MLS redeployment must also be carried out in the case of using the anti-hail rockets with trajectory characteristics that are significantly different from the trajectory characteristics of the previously used anti-hail rockets. During the off-campaign period, all MLSs arrive at a specially equipped parking lot, where they are
parked until the start of the following campaign. It is advisable to organize this parking lot next to the off-campaign rocket storage facility. At the beginning of the new campaign, the MLSs move into the preselected positions, self-propelled or in tow, with an operational reserve of anti-hail rockets. During the campaign, the MLSs are supplied with anti-hail rockets and other consumables in the same way as the fixed LSs.

When using the MLSs in the area where hail suppression activities are currently being carried out, they are deployed in addition to the already operating fixed MLSs. And in this case, the locations of MLS deployment are determined according to the methodology described in [3]. In other words, the MLSs must be moved into the positions most exposed in terms of hailfall occurrence.

At this stage, the tactical and technical requirements for the MLSs are as follows:

1. Platform for the MLS can be a carrier truck or a towed trailer with a carrying capacity from 1500 to 2000 kg.
2. Launcher with remote control must be carried on the platform of the carrier vehicle or trailer.
3. Number of launcher guide rails must be from 16 to 36 units.
4. Guidance in Azimuth must not be limited.
5. Elevation guidance range not less than from 0° to 80°.
6. MLS weight must not exceed 500 kg.
7. Rocket launch control must be carried out, using the remote control panel installed in the cab of the carrier vehicle or in living quarters.
8. Cab or living quarters must be equipped with a radio station to communicate with the command post and other MLSs.
9. Container with operational stock of anti-hail rockets prepared for operation in the amount of approximately 50 units must be placed on the platform of the carrier vehicle or trailer.
10. Electric generator must be placed on a platform and used to recharge rocket launcher remote control battery, firing battery, radio station battery, as well as for lighting needs.
11. During transportation, a residential module of the «house on wheels» type must be attached to the carrier vehicle and be suitable for the comfortable accommodation of two persons on duty for two days.

4. Conclusions

The use of the MLSs in the hail protection network will allow enhancing the range of possibilities in the fight against hail that were not available within the old system when using only fixed LSs. The main advantages of MLSs include:

- possibility to adjust the location chart of LSs to the trajectory characteristics of the used anti-hail rockets;
- possibility to adjust the LSs location chart to the changing external factors, such as a changes in the aerological situation in the target area or a change in the configuration of the target area that occurs even during one campaign;
- possibility to obtain an universal platform that is suitable for both hail suppression and precipitation enhancement operations by rocket method;
- possibility to perform the experimental work of modernization of the existing technology of hail protection by carrying out field experiments outside the protected area.

References

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