Scattering of fogs and clouds of the lower tier

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Abstract: The paper presents the results of numerical modeling of active effects on warm fogs and clouds of the lower tier, as well as the results of field experiments on the creation of illumination zones in these fogs and clouds (increasing the meteorological visibility range (MVR)). A cylindrical volume filled with a combustible composition of high calorific value with a highly dispersed powder of calcium carbide was used as a heat source (exposure model). When the heat source is triggered, 104 kcal kg⁻¹ of the fuel composition is released. Numerical modeling has shown that after 5–6 seconds after the thermal source is triggered, the MVR increases to 2 km (from the initial 50 m). Field experiments have shown an increase in the MVR by 5–50 or more times at different values of the meteorological parameters of fogs and clouds of the lower tier.

1. Introduction

Of all the currently available methods of scattering (clearing) warm fogs and clouds of the lower tier: dynamic, acoustic, electric, optical (using optical quantum generators) and others, the most effective method is thermal. The principle of the thermal method is that when the air with hydrometeors suspended in it is heated to a temperature above the dew point, the latter evaporate and gaps appear in the fog [1, 2]. It is necessary to reduce the relative humidity from 100 to 94–95% to scatter the fogs, so that the water droplets evaporate and the resulting lumen remains unaffected by the fog for some time. It is necessary to increase the temperature by 1.35–1.5 °C at an initial temperature of 0 °C and by 1.25–1.45 °C at an initial temperature of 5 °C, in order to reduce the relative humidity to 94-95% (the water content of the fog is assumed to be 0.2 gm⁻³). Knowing the temperature of the superheat, it is easy to calculate the amount of heat that must be introduced into the treated area of the fog to disperse it. The difficulty lies in the choice of the mechanism of propagation of the introduced heat to the entire volume of the clarified fog in a short time. As a rule, in fog, the turbulent movements are very weak, the turbulence coefficient is only a few square meters per second.

To solve this problem, when scattering warm fogs, we conducted field experiments in which heat sources were dispersed over a horizontal area in a staggered order at a distance from each other, providing a quasi-uniform distribution of a sufficient amount of heat per unit area. The vertical heat transfer is carried out by lifting the heated cloud air. The high temperature and power of heat sources quickly «work out» the volume of fog clearing. Depending on the thickness of the fog and its horizontal extent, the power and number of heat sources are selected.

The article briefly presents the results of numerical modeling of active impacts on the cloud environment (fogs and clouds of the lower tier) by heat sources, as well as the results of field experiments on the scattering of warm fogs and clouds of the lower tier.
2. Numerical simulation of active effects on warm fogs and clouds of the lower tier

On the basis of numerical modeling (according to the Russian State Hydrometeorological University (RSHU) model) of the active impact on fogs by heat sources, the change in time (τ) (since the beginning of the thermal impact) of the fog parameters – meteorological visibility range (MVR) \( L_1 \), water content \( q_1 \), supersaturation \( \delta \) and temperature \( t \) of the fog at a distance from the heat source of 10 m (designations with index «1») and 20 m (designations with index «2») is obtained (figure 1). It is conventionally assumed that at 1012 seconds, the heat source begins to act. It warms the air according to a linear law with an intensity of 2 degrees \text{c}^{-1}. After 1012 seconds, an intense heating of the air begins. As a result of a sharp decrease in supersaturation, the droplets rapidly evaporate. After 5–6 seconds, the MVR \( L_1 \) becomes more than 2 km.

3. Field experiments on cloud scattering

The experiments were carried out at the research sites of the High-Mountain Geophysical Institute in the North Caucasus. The research sites were equipped with means of active impacts and means of technical control of the results of active impacts [2].

It is experimentally obtained that the specific amount of heat \( Q \) depends on the superheat \( \Delta t \) and the water content of the fog \( q \). The greater the \( \Delta t \) and \( q \), the more heat is required per unit of the fog volume to be cleared (figure 2).

The values of \( \Delta t \) and \( Q \) depend on the temperature of the fog \( t \). The higher \( t \), the lower the \( \Delta t \) and the specific heat \( Q \) (figure 3).

Based on numerical simulations and the results of field experiments, the main technical requirements for heat sources for the dispersion of fogs and low layered clouds are determined. The heat source (exposure model) is a cylindrical volume filled with a high-calorific value combustible compound and a highly dispersed calcium carbide powder, separated from each other by a cardboard inner cylinder. Depending on the parameters of the dispersed fog, the heat source is equipped with a combustible composition weighing 1–10 kg and calcium carbide weighing 2–3 kg. When the heat source is triggered, a large amount of heat \((1–10) \times 10^4 \text{kcal} \) is released as a result of the combustion of the fuel composition, and calcium carbide powder is scattered in the illuminated volume of the fog.
Calcium carbide reacts with moisture, and, as a result of the exothermic reaction, heat is released. In addition, the calcium carbide powder, adsorbing moisture on itself, reduces the water content of the fog, and at the same time, as a result of the coagulation of powder particles with cloud droplets, they grow to the size of particles falling out under the influence of gravitational forces. These three factors contribute to the dispersion of the fog.

Tests of heat sources on the earth's surface and at various altitudes were carried out. The change in the power $Z$ (height) of the «cloud» formed when the heat source is triggered and the diameter of its
horizontal cross-section $X$ with time $\tau$ is obtained. In the initial period (5–7 s), the geometric dimensions of the «cloud» increase rapidly, and then slow down (figure 4).

![Figure 4](image)

**Figure 4.** Change in the vertical power $Z$ of the «cloud» formed when the heat source is triggered, and the maximum diameter of its horizontal cross-section $X$ with time $\tau$

When the heat source is triggered, the temperature in the fog increases. Figure 5 shows the distribution of the excess temperature with respect to the ambient temperature in the horizontal $l$ and vertical $h$ directions. The temperature $t$ was measured every 5 m horizontally and 2 m vertically. It is found that, depending on the power of the heat source and the values of $l$ and $h$, the overheating $\Delta t$ is 2–10 °C. The propagation velocities of air waves when triggered by heat sources are 460–600 ms$^{-1}$.

As a result of a large number of experiments (96 units), it was found that when fogs and clouds of the lower tier are dispersed by the thermal method, in all experiments, an increase in the MVR is observed by 5–50 times or more, depending on the parameters of the fog: visibility $L$, water content $q$, supersaturation $\delta$, temperature $t$, and the power of heat sources.

### 4. Conclusions

The thermal method of scattering of mists and clouds of the lower tier is based on the use of the heat source proposed by us, which releases heat energy due to: - combustion of a combustible composition of high-calorie substances $(1–10)10^4$ kcal; - spraying of calcium carbide powder together with the combustible composition in amounts of 1–3 kg in each heat source, in which heat is released as a result of exothermic reaction with cloud water and other factors.

Field experiments have shown an increase in the MVR by 5–50 or more times at different values of the meteorological parameters of fogs and clouds of the lower tier.

As a result of numerical modeling of the active effect on fogs and low clouds, we obtained: an intensive increase in the MVR ($L$) and the temperature in the fog $t$; and a decrease in the water content of the fog $q$, supersaturation $\delta$. 
Figure 5. Horizontal (a) and vertical (b) distributions of temperature excess outside the active zone of operation of a heat source of different capacity.

a) 1,5 – 5l; 2,3,6,10,11,12,13 – 3l; 4,9,14 – 2l; 7,8 – 1l; V₁=5l – dependence of 1,5; V₂=3l – dependence 2,3,8,10,11,12,13; V₃=2l - dependence of 4,9,14; V₄=1l - dependence 7,8.

b) 11 – 10l; 4,5,6,7,8 – 5l; 1,2,3,10,12 – 3l; 9 – 2l; V₁=10l – dependence 11; V₂=5l – dependence of 4,5,6,7,8; V₃=3l – dependence of 1,2,3,10,12; V₄=2l – dependence 9

References
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