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The acoustical methods of precipitation stimulations in natural clouds to get rains for agriculture

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Abstract

The different methods for stimulation precipitation from natural clouds are discussed to get rains. Presented technologies are shortly described. Artificial rains could be used as for agriculture, as for air purification and cooling directly in the atmosphere in warm and drought days.

Method background

Active methods for precipitation stimulation inside natural clouds are based on the fact that a typical cloud (~1 km³) can contain thousands of tons of water, because cloud moisture is about 1÷100 gram/m³. Only quarter of this water mass falls down during natural rains, so artificial precipitation enhancement for improving cloud seeding becomes more attractive every year. The most popular methods used today for creating artificial rain are the shrinking of hygroscopic small particles or of a special salt solution for 'warm' clouds and the introduction of glaciogenic substances into 'cold' clouds [1,2]. The aforementioned methods have been developed and thoroughly studied in experiments in Russia with high efficiency in practical applications [3]. They have shown good results during artificial stimulation enhancement, as well as a decrease of rain if necessary. There is short review with introduction to indicated topic and results. From the analysis of the relationship between the state of equilibrium for the cloud condensation nuclei and the relative air humidity, the resulting preference of poorly soluble substances was found for the introduction of the nuclei generated by artificial condensation for the modification of warm clouds and fogs [4,5] in addition to classical silver iodide and other methods. This study shows a fast increase of drops with radii ranging from 0.01 ÷ 0.1 µm up to 1 ÷ 3 µm. Such growth occurred inside the cloud in the first fifteen seconds after introducing the hygroscopic substances. The same first seconds demonstrate also fast changes in the main cloud characteristics, as the decrease of supersaturation and spectrum dispersion. This is accompanied by an increase of the radii in a drop. However, after the first major variations of these parameters they slowly increase with the same tendencies up to half an hour. This method proves to be the especial reorganization within small drops only and water vapors in the first few seconds, but it shows later a poor efficiency for the mentioned hygroscopic mechanisms. Further condensation and coalescence processes could be effectively continued with vibrations of the drop ensemble through the application of acoustical power inside the clouds. Each artificial hygroscopic particle or its natural analogous conglomerate is already completely saturated with water, so additional motions are necessary as a second step.

The acoustically influence to the area of cloud with aerosols tends to fast coalescence of drops, precipitation and seeding. The method of acoustically influencing natural aerosols, mists and fogs, was widely used from 1940s and counteracting industrial pollution was the central purpose for the development of this methods, also the acoustically influence for fogs and mists and they proved the high efficiency of this method [6]. However, this method was not later widely applied in practice, probably due to high noise in industrial areas and resulting impracticality of the method that prevented its real utilization. Previous result study shows three main disadvantages for today. Firstly, a complete theory that is strongly connected to the experiments in the real atmosphere should be further developed and improved. Secondly, most experiments were only carried out near the ground, but the method could be more effective by directly placing the sound generator inside a natural cloud at a height of 3 to 5 km into the region with supersaturated water steam. The sound generator should be placed inside a cloud through the use of modern aircraft. Particularly useful there are helicopters hovering in one area during a necessary time, but parachutes, balloons and planes would also be suitable, according to our calculation of times as 5-30 minutes.

The most interesting variant is a joint utilization of both methods at the same time, which means that hygroscopic particles and acoustic influence, which would be directly applied inside clouds to increase the precipitation significantly. The main idea behind combining both methods is that each has different functions that can reinforce and improve the overall effectiveness. Sound waves can easily provide additional motion for drops with greater velocities. The main kinds of movement for water drops triggered by sound waves are analyzed: (1) a drop's vibrations together with gas, (2) the circular motion together with gas and also the turbulent motion together with gas, (3) different kinds of a drop's drift. The drift can be caused by a number of

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phenomena, such as: (3.1) the pressure of sound irradiation, (3.2) pulses of viscosity, (3.3) no symmetry of the sound-waves and other phenomena. Different additional forces and special kinds of interactions between drops will appear in the case of sound waves with greater power. And besides, the pressure pulses in sound waves can be exploited as additional increase of supersaturation and condensation [6-7]. Optimal frequencies were found during this regime of pulsing pressure: in spite of the additional air pressure disappears in some moments, but the condensation is not stopped then special frequency/power conditions could be kept. All mentioned phenomena increase the condensation and coalescence processes. Calculations show for example, that low power sound waves with an power of 0.1 W/cm² and f = 1 Hz can generate air vibrations with driving amplitudes for a water drops of ~35 to 57 mm with a radius ranging from 1 to 5 µm; high-power drift velocities are up to 40 cm/sec. In addition, acoustics/hygroscopic joint action could increase the variety of weather conditions for which these methods could be successfully applied to get the rain. Usually hygroscopic particles are dispersed by an aircraft into the lowest part of a natural cloud where rising air flows must have an air velocity of about 2 m/sec, which means that in the absence of rising air flows this method becomes ineffective. High acoustical power increases the area and real cases of a particular drop where hygroscopic methods are involved. The precise calculation of the regimes of artificial rain will bring the controlled cooling of the air within approximately the lowest height above the ground [8].

Resulting regimes for optimal acoustics inside clouds

I. The next promising regime was found through the calculations of the low-frequency vibrations [8,9], for example there are presented at *Figures 1* for frequencies of *f* = 10 to 100 Hz with acoustical power up to 1 kW/m². One can see that such regimes are very good for vibrated coalescence, because they can provide high velocity and drop's amplitudes. The advantage of a low-frequency regime is that no high acoustical power is required; but low power acoustical generator is simpler with respect to device design and in the later practical realization. Such regimes are particularly relevant inside natural clouds. According to measurements the number of water drops inside natural clouds with typical radii of r = 1 to 50 µm is N ~ 64 – 600 in 1 cm³. A simple estimation for average number of ~ 300 cm^{-3} show the area occupied by one drop is about 3.3 mm³, so the approximate distance between neighboring drops is L_m ~ 1.5 mm. As a result, these calculation permit finding the first optimal interval for practical utilization within the regimes with low acoustical power and no high frequencies $f \approx$ 20 to 50 Hz. In addition to presented data, calculations show that values for both considered parameters *L, V* will rapidly go up when the applied power Q will be increased according to these equations and results. For example, the comparison the high frequency acoustical influence in the range of several kHz with the low frequency acoustical influence in *Figure 1* which has the same acoustical power Q = 1 kW/m² were done. There is more attractive low-frequency regimes with 10 ÷ 50 Hz due to higher displacement $L \approx 3.6 \div 0.6$ mm in comparison with very small one L = 14 µm during 1 kHz influences for the same drops of a radius of r = 5 µm. So, the acoustical power should be increased significantly in kHz regimes.

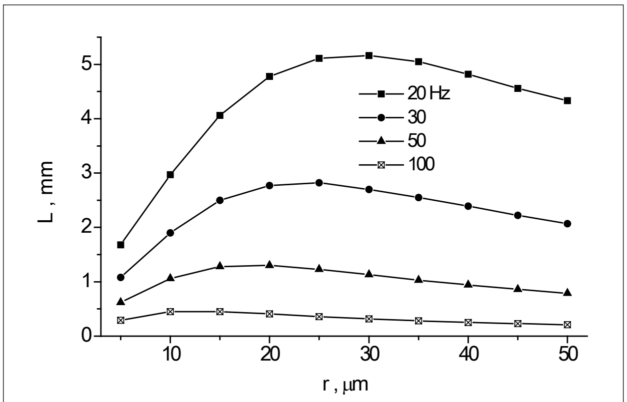

Figure 1: **The drop's displacement and velocity due to acoustical irradiation; these parameters are: frequency *f* = 20, 30, 50 and 100 Hz with a acoustical power Q = 0.1 W/cm².**

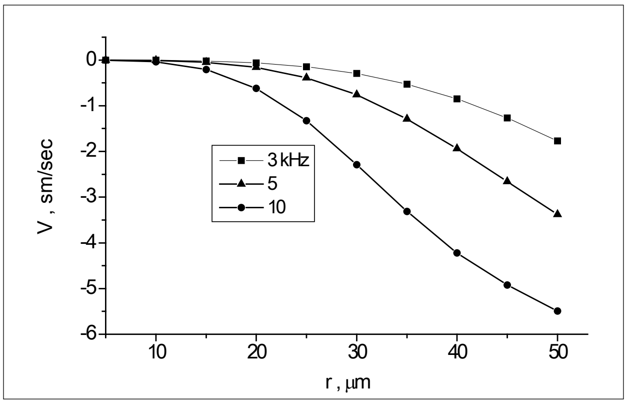

Figure 2: **Asymmetry–wave drift V_h in the sound wave with frequency 3, 5 or 10 kHz and power Q = 1 W/cm². (Negative values means the direction of drop's motion to the sound source.)**

II. The character of the motion for the rain drops caused by the high power of acoustical waves changes from oscillation to motion in one direction (drift). Most experiments with high acoustical power were performed in a range of 1 to 10 W/cm² with high frequencies of 0.5 to 30 kHz, where optimum was found near 3 - 4 kHz. The drift based on the asymmetry of sound waves provides the highest velocities for considered cloud drops $V_h \approx 10 \div 40$ cm/sec in comparison with air viscosity and other kinds and reasons of the drifts. There sinusoidal wave is changed to a triangular shape due to high acoustical power. For the mathematical interpretation the triangular form of the sound wave should be presented approximately as the sum of the first and second harmonics P_1 and P_2, of the appropriate Fourier spectrum, their ration is titled h in the following. This wave asymmetry becomes greater with increasing distance from the source x, also with its frequency f and sound power Q; and wave profile becomes more abrupt according to the distance up to certain overflow region x_m. For example, then asymmetry strong and h = 0.25, $\Psi=\pi/2$ this kind of drift show enough good velocity $V \approx 0.01 \div 16$ cm/s for the drops of $r = 10 \div 50$ µm then $Q = 1$ kW/m² and $f = 5$ kHz (*Figure 2*). Another mechanisms for the drop's drift was indicated also, as sound pressure to drops as the surrounding viscosity. First one provides negligible small values of drift, but air viscosity can give speed up to 5 cm/sec. There viscosity variations follow to the temperature variations in sound waves with producing an additional one-directional force, which means physically the difference of the Stock's reaction during horizontal oscillating air motion in sound wave. Calculation show also that lifting of the sound generator to an altitude of several km with a specially equipped modern aircraft would be very effective due to the significant increase of the method's efficiency according our calculations. This has the additional advantage of reducing the noise levels for citizens near the ground.

Conclusion

The series of technologies for precipitation stimulation inside natural clouds was described. Mechanisms of acoustical driving for typical water drops in clouds were analyzed. Two intervals of optimal regimes were found as low frequency and low acoustical power (I) or high frequency with necessary high power (II).

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