CLOUD SEEDING OPERATIONS TO MODIFY WEATHER CONDITIONS OVER CITIES: 2003-2006

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Abstract

Some results of activities on cloud seeding operations to modify weather conditions over Moscow and St.Petersburg (Russia) conducted during 2003-2006 are presented. 18 operational works on improvement of weather conditions were executed during this period. The main purpose of these works was the dissipation of clouds and reduction or stopping of precipitations over the protected cities during the large social, sporting or other special events.

Four basic concepts of cloud dissipation and precipitation redistribution were applied to improve the weather conditions depending on a weather conditions, type of clouds and intensity of precipitation processes: 1) dispersion of stratiform clouds; 2) destruction of convective clouds by a dynamic method; 3) premature rainfall initiation windward of the city with the purpose of the formation of a “rain shadow” (i.e. reduced rain) and 4) intensive seeding of the rain-producing cloud layers with the purpose of “overseeding”.

Up to 12 aircraft, such as Il-18, An-12, An-72, An-30, An-26, An-28, An-32 and M-101 “Gzhel”, specially equipped with the meteorological equipment, data acquisition systems, “Land – Aircraft – Land” data transmission system and means for cloud seeding have been prepared for fulfillment of the works. Liquid nitrogen, granulated carbonic acid (“dry” ice), meteorological silver iodide cartridges and packages with coarse-dispersion powder were used as reagents for seeding of clouds. Management of works and the control of results were carried out with the help of the automated radar systems MRL-5 – AKSOPRI in Moscow and MRL-5 – MERCOM in St.Petersburg.

1. Introduction

In weather modification research in Russia, special attention was given to the development of methods and technical means for dissipating clouds of some forms and preventing or substantially reducing precipitation amount. The practical objectives were to change radiation balance and to increase the income of solar radiation, to reduce municipal expenses for snow removal and clearing the roads and streets in large cities, to create favorable meteorological conditions for carrying out social programs, sporting competitions or some other situations when the necessity may arise to reduce the rainfall. The first experiment on practical application of these opportunities was carried out during eliminating the consequences of Chernobyl disaster in 1986 /Beriulev et al. 1990/. Since 1995 the organizations of ROSHYDROMET conducted more than 30 works on improvement of weather conditions in areas of the large cities – Moscow and St.Petersburg (Russia), Tashkent (Uzbekistan), Astana (Kazakstan) /Bedritsky et al. 1996, Belyaev et al. 1996, Korneev et al. 2003/. The main purpose of these activities was the dissipation of clouds and reduction or stopping of precipitations over the protected cities.

2. Main cloud seeding concepts

Four basic concepts of cloud dissipation and precipitation redistribution are generally used depending on a weather conditions, type of clouds and intensity of precipitation processes:

1. Dissipation of cold stratiform clouds.
2. Prevention or reduction of the intensity of shower rains and thunderstorms by a dynamic technique.
3. Premature rainfall initiation from cloud systems windward side of the target area with the purpose of formation of a “rain shadow”, i.e. reduction of precipitation over the given site.
4. Reduction of rainfall intensity over the given site by intensive seeding the rain-producing cloud layers moving toward it, aimed at weakening the mechanism of precipitation generation through the “overseeding” of clouds, i.e. creating excessive concentrations of ice crystals.

All these methods are based on the unstable state of atmospheric processes. Of the various types of instability, those with most potential for local modification of precipitation and cloud-formation processes are the phase stage of cloud water (existence of supercooled liquid water) and the convective instability of the atmosphere.

The feature that the first and the last two concepts have in common is the use of ice-producing agents

The first concept was to dissipate stratiform clouds or to reduce precipitation falling from them over the target site. Studies have shown that in certain conditions seeding of stratiform clouds with an ice-forming agent ("dry ice" or liquefied nitrogen) and aerosols (silver iodide) either leads to their dispersal or enhances precipitation from them over a certain period, followed by a further relative reduction of the intensity and amount of precipitation ("rain shadow"). Thus, by causing a relative increase in precipitation at an appropriate distance windward from the target area it is possible to ensure that the dispersal or "rain shadow" zones are located over it.

The second concept was to suppress the development of convective clouds using coarse powders. The methods to destroy developing convective clouds, using artificially generated downdrafts, were theoretically justified and thoroughly tested under laboratory and field conditions /Petrov 1986, Belyaev et al. 1987/. It is based on artificial initiation of downdrafts in convective clouds by releasing powdered agents into their tops. As was shown in CAO experiments /Belyaev et al. 1987/, this method has proved sufficiently effective – up to 90% for single-cell isolated air-mass clouds, and 60-65% for frontal clouds.

The other two methods (third and fourth concepts) use weather modification techniques similar to that employed in the first method aimed at the dissipation of clouds.

In both cases it is possible to estimate the distance of advance seeding relative to the protected territory so as to prevent undesirable clouds and precipitation from reaching it.

The fourth concept of cloud modification aimed at reducing precipitation over target area consist in seeding rain-producing cloud systems on the windward side of protected territory with above-normal quantities of ice-forming agent. Overseeding, i.e. producing ice crystals inside clouds in concentrations many times those of naturally generated ice, brings about a situation an abrupt increase of the number of simultaneously growing precipitation particles is accompanied by a marked slowdown in their growth and a reduction of their falling speed. This, in turn, leads to noticeable temporary reduction of precipitation. In cloud overseeding operations, the distance of seeding paths from the borders of the protected territory is chosen so as to be approximately the same as the distance of a half-hour or one-hour wind transport of clouds.

3. Technical means

The described methods were realized using specially instrumented aircraft of different types. In complementation to the Velocity of ascent types, used in 1995 – 2002 (Il-18, An-12, An-30, An-26 and An-72), three new types of aircraft – An-28, An-32 and M-101T "Gzhel" were used in weather modification activities in 2003 – 2006.

An-32 aircraft (Fig. 1) differs from An-26 aircraft, used in works to modify weather conditions over cities, of the greater velocity of ascent and the greater carrying capacity, and also higher practical ceiling of flight (more than 9000 m).

Figure 1. Aircraft An-32

For carrying out of cloud seeding operations the An-32 aircraft was equipped by: the device for dropping the packages with coarse-dispersion powders, means for cloud seeding using dry ice and liquid nitrogen generator GMCHL-A.

The aircraft of the middle class, Ан-28 (Fig. 2), as well as Ан-32, for the first time has been used in works to modify weather conditions over cities in 2006.

Figure 2. Aircraft An-28

The charge of fuel of An-28 aircraft is 350 kg/hour. The weight of useful loading of the plane makes 1800 kg that has allowed simultaneously with four members of crew, to place onboard of the plane a nitrogen generator and 20 packages with coarse-dispersion powders.

Aircraft M-101T "Gzhel" (Fig. 3) is intended for performance of works on cloud seeding. This aircraft has the low charge of fuel (100 kg/hour).

Figure 3. Aircraft M-101T "Gzhel"

The M-101T "Gzhel" aircraft is equipped with easily removable onboard complex of the measuring equipment and technical means for cloud seeding. The means for seeding include the nitrogen generator of ice particles (Fig. 4) and a system to release 256 silver iodide pyrotechnic PV-26 flares (Fig. 5).

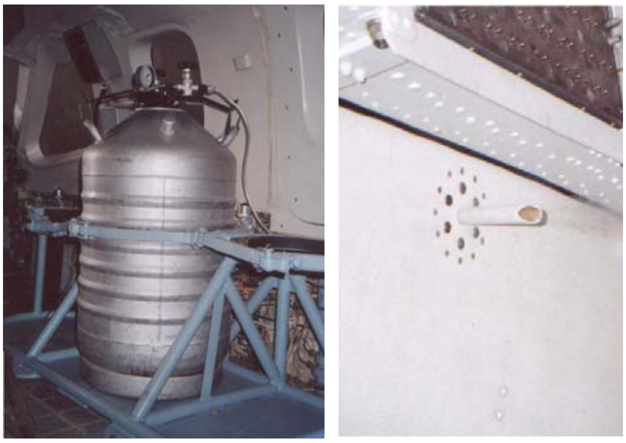

Figure 4. The nitrogen generator of ice particles, installed onboard of M-101T "Gzhel" aircraft

Figure 5. A system for shooting pyrotechnic PV-26 flares

In 2004 information-measuring system, used for weather modification activities, was complemented by data transmission system "Land – Aircraft –Land" /Petrov, et al., 2007/. This system allows to display the locations and flight paths of aircrafts on monitor of the automated radar system, as well as send aboard the aircrafts radar maps of distribution of cloud and precipitation in region of works. Each aircraft participated in these activities was equipped with on-board kit of this system. In the control center the Base kit of this system was installed (Fig. 6).

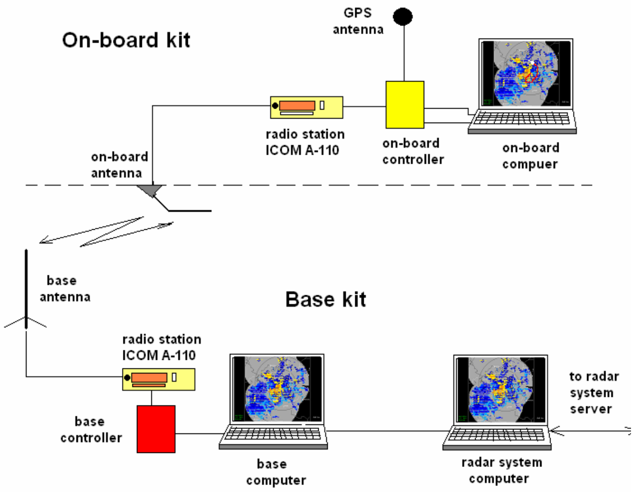

Figure 6. Data transmission system.

As an example, trajectories of airplanes imposed on the radar-tracking image of the top clouds are presented on Fig. 7.

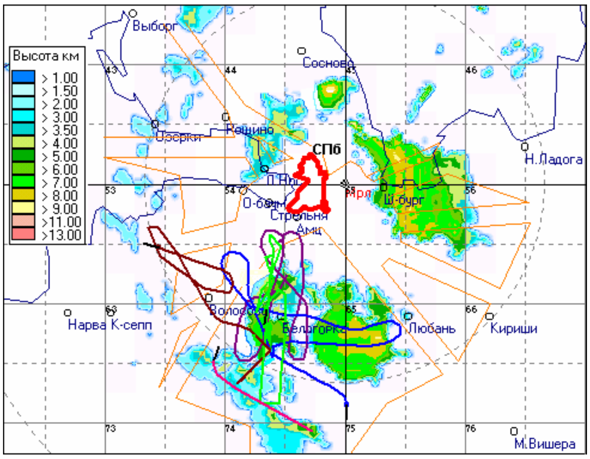

Figure 7. The trajectories of aircrafts imposed on the radar-tracking image of the top cloads.

Management of works and the control of results were carried out with the help of two wavelengths MRL-5 meteorological radar, equipped with the automated radar system AKSOPRI, installed in Moscow (Krylatskoye) and the system MERCOM in St. Petersburg.

4. Results of an improvement of weather conditions

All the methods and technical aids described above were employed successfully in the activities associated with eliminating the consequences of Chernobyl disaster in 1986, and improving weather condition in Moscow (in 1995-2002), Tashkent (in 1994-2002), and Astana (in 1998) /Korneev et al., 2003/. Some characteristics and results of an improvement of weather conditions in Moscow and St.Petersburg cities conducted during 2003-2006 are presented in Table 1.

The seeding effect was monitored using the network of four automated radar systems MRL-5 –

AKSOPRI in Moscow area and radar system MRL-5 – MERCOM in St.Petersburg, and raingauge data. Analysis of these information showed that due to cloud seeding it was possible: 1) to attain the destruction of stratiform and precipitating convective clouds, or 2) to obtain the considerable, 2-10 times decrease of intensity and amount of precipitation over the protected territories in comparison with rain fallen upwind and in its nearest surroundings, thus demonstrating the effectiveness of cloud seeding operations, conducted in Moscow and St.Petersburg during 2003-2006.

Table 1. Characteristics of cloud seeding operations on an improvement of weather conditions over Moscow and St.Petersburg (Russia) conducted during 2003-2006.

Event	**Date**	**Number of aircrafts**	**Number of flights, duration of flights**	**Precipitation**	
				target area	**neighborhood**
Day of the Victory (Moscow)					
2003	9 May	10 aircraft	1 flight, 5 h 10 min	no rain	no rain
2004	9 May	10 aircraft	13 flights, 65 h 05 min	to 1-2 mm	to 4-5 mm
2005	7- 9 May	12 aircraft	35 flights, 214 h 08 min	7 – no rain 8 – to 0.2 mm 9 – no rain	7 – to 0.2 mm 8 – to 2-3 mm 9 – to 1-2 mm
2006	9 May	11 aircraft	14 flights, 80 h 39 min	to 0.5-1 mm	to 3-4 mm
Day of Russia (Moscow)					
2003	12 June	10 aircraft	10 flights, 53 h 51 min	no rain	to 0.5-1 mm
2004	12 June	10 aircraft	1 flight, 8 h 30 min	no rain	no rain
2005	12 June	10 aircraft	14 flights, 80 h 56 min	no rain	to 0.3-0.5 mm
2006	12 June	7 aircraft	9 flights, 48 h 57 min	to 0.3-0.5 mm	to 2-3 mm
Day of Moscow city					
2003	6-7 Sept	10 aircraft	11 flights, 64 h 33 min	6 – to 0.3 mm 7 – no rain	6 – to 2-3 mm 7 – no rain
2004	4-5 Sept	10 aircraft	5 flights, 31 h 38 min	no rain	no rain
2005	4 Sept	10 aircraft	6 flights, 49 h 06 min	no rain	no rain
2006	2 Sept	11 aircraft	6 flights, 26 h 07 min	no rain	to 0.2-0.3 mm
300th anniversary of St.Petersburg, 2003	30-31 May	7 aircraft	18 flights, 91 h 57 min	30–to 0.5-1 mm 31– to 0.2 mm	30 – to 2 mm 31 – to 0.5 mm
The International tournament on athletics "Moscow challenge", 2003	20 Sept	10 aircraft	4 flights, 21 h 42 min	no rain	to 0.5-1 mm
The sixth Moscow festival of beer, 2004	10 July	10 aircraft	1 flight, 5 h 00 min	no rain	no rain
Day of the Railwayman (Moscow), 2006	6 Aug	8 aircraft	8 flights, 23 h 24 min	no rain	to 2 mm
"Scarlet sails" open air festival (St.Petersburg), 2006	23-24 June	6 aircraft	6 flights, 45 h 14 min	no rain	to 5-10 mm
The Summit of "The big eight" (St.Petersburg), 2006	15-17 July	11 aircraft	20 flights, 138 h 10 min	15 – no rain 16 – to 4-5 mm 17 – to 0.5 mm	15 – no rain 16– to 30-40 mm 17 – to 4-5 mm

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