Adjustable updrafts in the atmosphere and stimulation of precipitation

Abstract

The following method and the corresponding device are proposed for producing ascending air flow in the free atmosphere to adjustable height which is capable of overcoming temperature inversion layers in an anticyclone. The main goal is to artificially create the clouds and stimulate rainfall (precipitation). The proposed method and the device can also be used for the dispersion of fog and general industrial air pollutions such as smog or mining dust. The device can also be used for meteorological studies of atmospheric processes under controlled conditions.

The problem definition: In order to cause precipitation, it is necessary to displace ground-level air to a required altitude (to the cloud-formation level) and to provide this air with the condensation centers. On the path of the raising air, it is necessary to punch through the levels of temperature inversion, to overcome the downward air fluxes in anticyclone, and to trigger the powerful self-sustaining process of cumulonimbus clouds formation by condensation of atmospheric vapor causing the formation of a rainfall.

The method: At several levels, ascending air is heated, (as soon as the air cools), by a system of tethered aerostats with blackened balloons, which make use of the solar-radiation energy. Additionally, the ascending air is saturated with negative ions.

Description of the device. The device (called HELIATOR) consists of a multi-tiered system (garland) of tethered blackened balloons. At each tier, the blackened balloon surface is heated by the Sun and transfers its heat to the surrounding air by convection. Ascending and expanding air is cooled and then reaches the next level. As a result of the process repeated for all tiers, flexible and adjustable ascending flows of heated air are formed. The required altitude corresponds to the dew point, where there occurs the condensation of water vapor into cumulonimbus clouds causing precipitation. There is also a system of grounded electrodes emitting electrons located at the tiers. The emitters produce the corona discharge which develops in the Earth electric field and supplies ascending air flows with negative ions, i.e., with efficient centers of condensation. The altitude of the upper and the lower tiers, their shape, size and spacing between them are determined by both the weather conditions and the task to be solved. The energy consumed by the device is provided by the solar radiation and by the stationary Earth electric field. There is no need in additional energy sources and expense materials. Full environmental cleanness is also provided.

There are no known analogs of any similar multilevel clean activation of the raising air flow by solar radiation and the electric field of the Earth in the world. This method and design are protected by the **Patent No. RU 2462026, author V.P. Pavlyuchenko** (pavict@rambler.ru), the patent holder is **P.N. Lebedev Physical Institute of RAS**

Keywords: meteorology, an anticyclone, cumulonimbus clouds, precipitation, active influence, updrafts, free convection, artificial rain, environment, ventilation, ground-level pollution, tethered balloons, solar radiation, condensation nuclei, ions, corona discharge, the electric field of the Earth

1. Introduction

At present, the global shortage of the fresh water in the world is rapidly growing.

The consequences of such shortages are droughts, environmental degradation, and the growth of deserts which have become a natural and social disaster affecting many human aspects that require attention and immediate action. As the UN Secretary-General Ban Ki-moon stated in a report on the occasion of the World Water Day, March, 22, 2010, a child dies every 20 seconds in the world from diseases caused by the lack of clean water. About a quarter of the world's population, according to the World Health Organization, gets sick by drinking the bad water.

Environmental disasters: The Aral Sea, Sahara.

According to analysis of MGIMO (Moscow State Institute of International Relations, 2011), an acute shortage of drinking water may occur earlier than that of the oil, with corresponding aggravation of inter-state conflicts.

Understanding the seriousness of global trend towards reduction of the living space and catastrophic rise in water scarcity was shown in decisions of the United Nations. The problem of drinking water and access to its consumption is recognized as one of the most important objectives of the Millennium Development Goals, the UN Millennium Declaration in 2000.

In 2003 the UN General Assembly declared the years 2005 - 2015 as International Decade for the "Water for Life" Action (resolution 58/211), and in 2007 the period of 2010 - 2020 was declared as the United Nations Decade for Deserts and Desertification (resolution 62/195).

Periodical drought in the main grain-producing regions and severe economic and environmental impacts of unusually hot and dry summer of 2010 in central Russia have clearly shown the importance of the problem, even at middle latitudes in present conditions, and the inoperability of the previously proposed methods to struggle against the drought.

By availability of the fresh water resources Russia is on the 26 place in the world (in cubic meters per capita per year):

French Guiana 609 091, Iceland 539 638, Guyana 315 858, Suriname 236 893, Congo 230 125, Papua New Guinea 121 788, Gabon 113 260, Bhutan 113 157, Canada 87 255, Norway 80 134, New Zealand 77 305, Peru 66 338, Bolivia 64 215, Liberia 61165, Chile 54 868, Paraguay 53 863, Laos 53747, Colombia 47365, Venezuela 43 846, Panama 43502, Brazil 42866, Uruguay 41505, Nicaragua 34710, Fiji 33827, Central African Republic 33 280, **Russia 31 833**.

The artificial activation of precipitation can reduce the tension of the situation with fresh water, especially for the environment and agriculture, and it is the main goal of this project. The water vapor is always present in the atmosphere and its total amount is six times above that of the fresh water in all the rivers in the world. Even a small rain-shower can produce thousands of tons of fresh water.

In general, the application of this method may safely reduce the excess energy pent up in the atmosphere in a form of the heat and moisture diminishing the risk of some catastrophic weather events. Variations in the weather pendulum "drought - flood" may be reduced.

2. Physical basis of the precipitation formation

The basis of precipitation is condensation of atmospheric water vapor as it is cooled down to the point of dew (i.e. to 100% relative humidity).

In summer conditions the main precipitation kinds are the rain, drizzle, and, rarely, the hail.

The drizzle and finely dispersed steady rains occur over large areas from the clouds of upwards sliding in the region of atmospheric fronts, when the vertical component of the air flow velocity does not exceed tens of centimeters per second. At present, humans are not capable to exert any influence on formation and movement of atmospheric fronts having the length of hundreds and thousands of kilometers.

If the upward velocity component exceeds 0.5 – 1 m/s, the development of convective vertical cumulonimbus clouds emerges under favorable natural conditions resulting in torrential rainfall which is relatively short-living and limited in size. Sometimes, if the amount of heat energy and moisture in the atmosphere is large enough, the cloud's peak can reach the altitude of 10 – 12 km where the temperature is about -50° C, and the updrafts in the central part of the cloud may speed up to a few tens of meters per second, so the clouds develop themselves into thunderclouds with a heavy rainfall.

Later on, the attention will be focused on the cumulus clouds specifically, which cannot develop into cumulonimbus on their own because of the unfavorable conditions in a hot dry anticyclone or an insufficient supply of moisture.

Humidity. The atmosphere layer up to the height of 1.5 km above the sea level contains approximately 50% of the total amount of atmospheric water vapor, and the layer below 5 km contains up to 90%. The average water vapor content in the air is 28.5 kg over every square meter of the earth's surface (~ 15 kg/m^2 in the Arctic/Antarctic, ~ 25 kg/m^2 in Central Asia and above all deserts in the dry continental air, and up to 53 kg/m^2 above the ocean at equatorial latitudes).

The atmosphere can not contain any amount of water vapor above its upper limit (f_{max}) at each predetermined temperature (the dew point). If the amount of vapor exceeds the limit or the temperature drops the excess steam is condensed into liquid phase.

Table 1

The maximum amount of water vapor in the air at a predetermined temperature

dew point (°C)	−30	−20	−10	0	10	20	30	40	50	60	70	80	90	100
f_{max} (g/m³)	0,29	0,81	2,1	4,8	9,4	17,3	30,4	51,1	83,0	130	198	293	423	598

For example, during the hot dry weather (t = 40°C, relative humidity = 40%), one m^3 of the air contains about 20g of vapor and if such air is cooled down to 20°-22° C the saturation occurs and condensation will start.

Essentially, the **atmosphere** consists of nitrogen (78%), oxygen (21%), water vapor, and of the more rare gases. In its steady state the atmosphere temperature decreases with altitude, on average by 0.65 C degrees per 100 m. Under anticyclone conditions, the temperature **inversions** will usually occur when the vertical distribution of the temperature deviates from its normal state, i.e. the temperature decrease slows down with altitude or even starts to grow. Temperature inversions create **inversion layers** which prevent air updrafts.

Because of its transparency, the atmosphere is heated by the Sun much less than is its heating from the underlying surface which transfers the heat to the air. Efficiency of the air heating through convection from the surface is some hundreds times greater than that of the radiation heating and hundreds of thousands times greater than the heat transferring efficiency due to a molecular thermal conduction.

Due to the temperature difference between different parts of the land the local upward flows of the hot air are created due to it being lighter than the cold air. Because of the Archimedes force the air heated at the surface rises up with an acceleration **a = g (ΔT/T)**. Here**, g** is the acceleration of gravity, **T** is the absolute temperature of the air, and **ΔT** is the difference between the temperature inside and outside of the ascending stream. As the unsaturated air rises up its temperature decreases because of the adiabatic expansion in the gravitational field of the Earth by about 1 degree per 100 m (a dry adiabatic process), i.e. it is faster than in stationary atmosphere, and therefore the updraft heated near the ground cools itself relatively quick to the surrounding temperature slowing the speed of rising until stopped. The temperatures are equalized especially quickly as it reaches inside an inversion layer. **The temperature inversion is a major obstacle to precipitation in an anticyclone (Fig. 1).**

An additional stimulus for the rising upstream may also be a local area of a higher humidity, since dry air is heavier than the wet one at the same temperature. With its initial humidity and temperature sufficiently high, the rising air sometimes succeeds to cool down to the dew point even before the updraft has stopped. Then the condensation begins, the air starts to self heat (in condensation of each gram of water vapor 600 calories are released, and the cubic meter of air warms up by 2 degrees), and the upstream rise continues with slower temperature decrease due to the warming from condensation (also known as the humid adiabatic process). It is this powerful self-sustaining mechanism which gives a high upward velocity to the cumulus clouds with vertical development.

Condensation of the vapor starts when the temperature decreases to the dew point (saturated vapor). This is facilitated considerably by the presence of the condensation centers in a medium; a considerable super-saturation is required to start the process in their absence. Condensation centers may be in a form of aerosols (with particles size below 1 micron), smog, dust, ions etc. Negatively charged particles are especially effective for the condensation to occur on.

The result of condensation is the formation of the **water drops.** During the initial cloud formation the drops have a diameter of 5 - 50 microns (fog). In the process the larger droplets are formed with a diameter of 50 - 200 microns (drizzle), which begin to fall slowly, but partially evaporate on the way to the ground never reaching it. Later the droplet's diameter can increase up to 500 - 5000 microns (rain drops) due to the coagulation of small droplets. This usually happens in the middle of cumulonimbus clouds, where the updrafts prevent the small droplets to fall down, giving them enough time to join into large drops. The biggest of the drops are the first to reach the ground, although they partially evaporate on their way cooling and humidifying the air; the smaller drops follow them.

Charged **ions** are constantly formed in the atmosphere, mostly by the cosmic rays in its depth. Usually, it is an electron detached from a neutral atom and the remaining positively charged atom, i.e. a pair of particles with the compensated charge. The average concentration of such ions is determined by the balancing of the rates of their origination and disappearance in recombination. Within 10^{-8} - 10^{-6} sec, the individual electrons are rapidly attached to oxygen O_2 or nitrogen N_2 molecules. In the case of O_2 molecule this process comes with release of heat due to the energy of the electron affinity to oxygen. The light ions, both atomic and molecular, can settle on aerosols suspended in the atmosphere to form larger and heavier ions with masses many times greater than the mass of the light ions.

The ions have a significant effect on condensation process: it is on the ions formed in a gas by the passage of a charged particle where a rapid condensation of vapor occurs and visualization of particle tracks in Wilson cloud chamber takes place.

3. Baric systems

The **cyclone** is a vast area of low pressure. The air rises up in the form of a funnel with the anticlockwise rotation in the Northern hemisphere and clockwise in the Southern one. When lifting, the air expands and cools adiabatically, the water vapor condenses, and the precipitation falls.

The **anticyclone** is an area of high pressure. The air moves downwards and rotates in direction opposite to that of the cyclone. During the descent, the cold air is compressed, heated, and dried up resulting in very little or no precipitation. Descending air spreads horizontally from the center to the periphery of the anticyclone. The temperature of each descending layer increases by 1° C per 100 m, so the layers which come from higher altitude pass longer distance in vertical direction and become heated more intensely. Thus **anticyclone temperature inversions** appear in the free atmosphere which cause inhibitory layers and prevent upward convective flows (Fig. 1). The thickness of an inversion layer varies from several meters to kilometers and the amplitude of temperature variation may exceed 10° C.

These two processes together with the atmospheric fronts are the main factors which form the weather. In the Figure 2, left, the plots of temperature (solid line) and dew point (dashed) are presented in their dependence on the altitude. In anticyclone (2) an upstream at low humidity can not overcome the powerful temperature inversion. The clouds are formed beneath, as the level of condensation occurs below the level of temperature inversion, otherwise it would be the cloudless weather. In the cyclone (1) two levels of weak inversion are shown, through which the powerful cumulus cloud made its way due to internal heating from the condensation of atmospheric vapor with a partial delay (horizontal spread of the cloud).

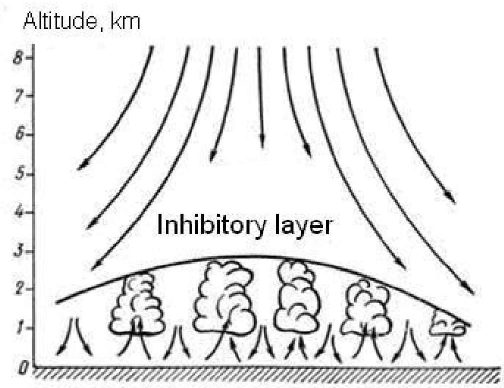

Fig.1. Scheme of weather in the summer anticyclone. Under the dome of the powerful inhibitory layer (inversion) local upward and downward atmospheric flows can be formed.

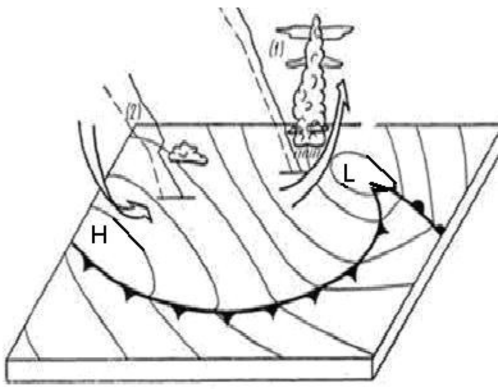

Fig. 2 Main pressure systems.
(1) - cyclone, low pressure, updrafts, convective cumulus cloud of the high altitude with precipitation. (2) - the anticyclone, high pressure, downdrafts, small cumulus "cloud of a good weather"

4. Artificial precipitation

Apparently, the history of the **fight against drought** is of the same age as the history of agriculture, often it was a matter of survival. In the places where artificial irrigation was impossible, a variety of different means to induce rain was used including quite exotic ones (witchcraft, sacrifice, etc.). During the wars of XVIII-XIX centuries it was noticed that the battles with intensive use of artillery (and with the use of the black powder), which began in clear weather, often ended in torrential rains. Then the experiments began which were focused on the artificial stimulation of precipitation.

Nowadays the **active clouds manipulation** for their dispersement is well practiced with the use of the silver iodide, dry ice, cement dust and other substances as additional centers of condensation. One of the methods proposed for the same purpose is based on a more eco-friendly principle and anticipates generation of additional ions by irradiating the clouds from airplane by an electron beam of moderate energy. Such a beam is fully absorbed in the atmosphere before reaching the ground but a large number of resulting ions activates the condensation.

In 1961 in France the **fire meteotron** method was patented with burning oil nozzles over a large area for condensation of clouds with precipitation even at a cloudless sky; the power of this installation is of the order of several Megawatts. The heated air together with combustion products rose up and the clouds appeared which sometimes dropped the rain. Later on, the retired aircraft engines were applied for that purpose. This method did not get widespread adoption because of the environmental and economical reasons.

More environmentally friendly is a **sunny meteotron** in which the air is heated from the ground surface of artificially blackened large area. This arrangement certainly works under natural conditions with both the temperature and humidity being high enough and without any strong temperature inversion. Nevertheless, in an anticyclone such favorable conditions are rarely satisfied and the heated at the ground flow of air is often trapped by an inversion layer because of the turbulent cooling and insufficient power of heating (in a cloudless day about 1 kW of solar radiation comes per 1 m^2 of the Earth's surface).

We did not address the many other proposals without any confirmed operation ability here. The most significant in this sense was the summer situation in 2010 when suffocating fog of the forest and peat fires hung over the Moscow region for about two months because of a strong anticyclone and high temperature of the air, but any attempts to induce artificially precipitation or at least to disperse the near-surface contamination were unsuccessful. It should be noted that these conditions have practically implemented the meteotron principle on a large area scale (strong ground fires), but it failed to break through the temperature inversion of anticyclone. Moreover, a strengthening of the inversion layer has occurred as the sun heated the upper air layers stronger because of the smog.

5. The proposed method and device for its realization (HELIATOR)

To cause an artificial precipitation in an anticyclone **two necessary conditions** should be fulfilled simultaneously:

1. A **source of energy** powerful enough must be present and effectively used to create and maintain a sufficiently rapid updrafts capable of breaking through the detaining inversion layers and downdrafts in an anticyclone and to reach the altitude where a powerful self-sustaining process of vertical development of the convective cloud will be switched on due to the vapor condensation.
2. The enrichment of the condensation region with the **condensation centers** of necessary concentration.

Additional conditions are the **environmental friendliness** and **low cos**t.

The **essence of the method** is in the use of the sunlight to heat a multi-level system (multi-tiered garlands) of the tethered blackened cylindrical balloons, which transfer the heat energy to surrounding air and create the free convective updrafts. The grounded sharp pointed emitters of the negative ions are fixed on the tiers which ensure necessary concentration of the effective condensation centers. Therefore, all the conditions necessary for an artificial precipitation are fulfilled:

- The Sun is the most environmentally friendly and widely available source of energy which naturally forms the weather. At the top of atmosphere it delivers 1366 W/m^2 and in a fair weather day about 1 kW/m^2 reaches the ground. On the land the bulk of this energy goes into heating the Earth's surface (90%) while the rest of it is re-emitted upwards. Thus, at all heights in the atmosphere the irradiation of a blackened surface and its isotropic heating reaches at least 1 kW/m^2. Heating of the surface continues until the dynamic equilibrium establishes between the energy supply and its transfer to surrounding air, mainly by convection ($\leq$ 10% goes to infrared radiation), which forms an upward air flow in atmosphere.
- A multi-level system is the most efficient way to heat an ascending air flow because the energy is supplied to the upward just at the time and in the place when and where it is most needed at the moment.
- The grounded needle emitters of the free electrons at each tier create the coronal discharge in a constant electric field of the Earth to supply the air flow with negative ions, which are ecologically clean and highly efficient centers of water vapor condensation.
- Complete environmental cleanliness is ensured by the lack of consumables and the use of the solar energy. Moreover, an artificial upward air flow carries away the dirt and heat from the earth's surface to the upper atmosphere layers efficiently where the heat is dissipated into the space. The increase of cloudiness, cooling and cleaning of the near-surface atmosphere by a rain also reduces the heat and improves the environment conditions during the drought anticyclone.
- The low cost of the whole installation is a consequence of the simplicity of its design which does not require any consumables or other expensive materials. The energy needs are fully provided by the solar radiation and the constant electric field of the Earth.

The system operates as follows. During the fair weather the balloons are filled with a gas lighter than the air and integrated into a single tethered system. The system is subsequently launched one balloon after the other from a well grounded start point. It is usually during the sunny days and when faced with an anticyclone with a weak wind when the need of the artificial upward flows and clouds exists the most, while during the cyclone the updrafts are formed without any human intervention. The surface of the balloons is blackened for a better absorption of the solar radiation. The balloons are attached to the frames (their shapes may be different) and are assembled in stacked tiers. An additional blackened layer may be placed on the land.

Let's consider the closed tier as a polygon or a torus formed by a tube filled with a gas bent into a circle and attached to a frame which has the shape of the rim of a bicycle wheel. This frame provides the rigidity for the whole tier and is attached to the tether. Holding wires (the spokes) are stretched between the rim of the frame and its center; simultaneously, they play the role of the electron's emitters.

The electric current needles and blade-shaped tips are used to enhance the emission power. One of the tethers is made of a electricity conducting material and connects all the emitters with the ground while all the others are insulators made of synthetic fibers for safety. The use of a light blackened metallized plastic film with a good thermal conductivity, such as the polyester (Mylar) is the most effective as the balloon shell material. It retains the gas at the atmospheric pressure well, is resistive to the UV radiation, and, together with the gas circulation inside the container, equalizes the heating temperatures of both the sunny and the shaded sides of the shell. To increase the area of the solar heating an additional light blackened film is hung around the perimeter and/or between the tiers. The tie-down roping of a required length are attached to the winches.

The blackened tubes of all tiers are heated by the Sun and transfer their heat to the surrounding air which results in a ring-shaped torch of natural convection above the heated surfaces in each tier. The lighter warm air rises up with acceleration due to the Archimedes force. It gradually cools itself due to the expansion and turbulent mixing with the ambient air at the periphery, at the same time the heated convection torch focuses towards the axis of the symmetry with the height. This results in an automatic self-focusing of the convective flow (Fig. 3). Such a heating process repeats itself at each tier up to the very top one.

The height between the tiers is chosen such so that the air in the updraft doesn't cool down to the ambient temperature before reaching the next level sustaining a continues up flow, otherwise a single system HELIATOR splits into independent solar meteotrons with small footprint and efficiency.

Under the controlled conditions an upward stream of heated air is created along the vertical axis of installation in the form of a flexible trunk with required height. The overcoming of downdrafts and temperature inversions on its way through atmosphere is adjusted automatically: as an upstream rate slows down the more intense warming of the air arises on respective tiers due to its prolonged contact with the surface. Additional "manual" control may be achieved through the change of the distance between the tiers and/or hanging of the additional heating surfaces in the temperature inversion region.

Fig. 3 presents an upstream calculation at the two lower tiers of a multi-tier system, assuming the temperature of the heated balloons being 40º C while the temperature of the ambient air is 20º C (the temperature difference between the blackened surfaces in the sun and in the shade varies from 20º to 40º C). The diameter of the tier is 20 m, while the cross-section diameter of the gas-filled tube is 3 m, the distance between the tiers 25 m, the height of the lower tier 10 m above the ground. It is evident that the specified distance between the tiers and the height of lower tier can be augmented without any significant loss in the flow intensity which may reduce the number of necessary tiers and to save material with the height of the whole installation kept constant.

The controllable upward air flow heated in this manner at several levels can overcome the inverse layer and reach to the last tier at the altitude where the water vapor begins to condense. Thus a strong self-sustaining process of cloud formation starts through continuous supply of the near-ground air. Fig. 3 shows that the air is involved in the flow mainly from the bottom side of surface layer where the amount of moisture and aerosols (dust, smoke, fog, soot, etc.) is the highest. The aerosols together with the long-living ions create additional effective condensation centers above while the near-surface air becomes clean, and these contaminants play an important positive role in the water condensation process while being raised to the top.

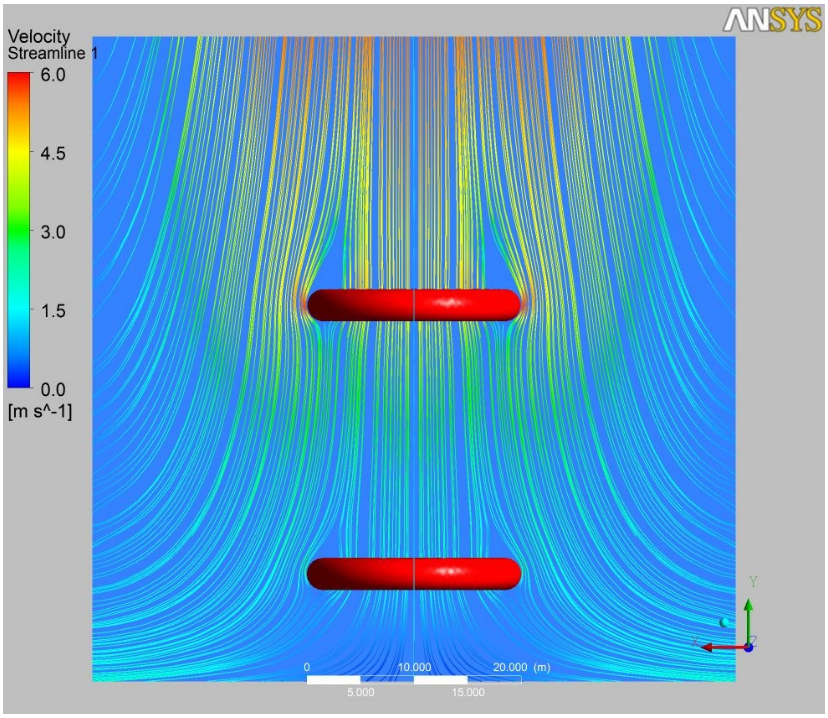

Fig.3. The calculated velocity distribution of the heated air in the upstream system HELIATOR (2 lower tiers, calculation of L.L. Teperin)

The positive difference of the electric potentials between the ionosphere and the Earth's surface is about 400 kV. This causes a constant weak current in the atmosphere. This current transfers an average of 60 coulomb per year on a 1 km^2 of the surface of the Earth and discharges the capacitor between it and the ionosphere. The negative charge of the Earth is restored during thunderstorms by lightning strikes and permanent corona discharges from any grounded sharp points.

Corona discharge is the smoldering self-dependent electric discharge which occurs in a gas inside a highly inhomogeneous high-voltage field in the vicinity of an electrode with a small curvature radius. The smaller the radius of the curvature, the higher the field at the same difference of the electrical potentials. Within the quiet atmosphere conditions the electric field in the first 2 km above the sea level is about 100 – 130 V/m so, the voltage difference between any grounded emitter and the equipotentials in the atmosphere occurs on the order of 30 kV or more at an altitude of ≥ 300 meters. In such conditions the corona discharge at a thin conductor, especially on a sharp point, is extremely intense, and the current is limited only by the amount of accumulated spatial charge near the conductor edge which screens the field. Free electrons during 10^{-8} - 10^{-6} sec are captured by neutral molecules or micro-particles, and form the long-living condensation centers with **uncompensated charges** with the mobility of 1 - 5 cm/sec in the electric field of the Earth.

Within each tier there is a system of grounded wires-emitters with sharp points, through which upward flow passes. The flow carries away accumulated negative space charge because its velocity – some meters per sec – is much greater than electrons mobility. The electric force acting on electrons in the Earth's field is added to the Archimedes force.

The condensation in atmosphere **may start** only if the temperature of water vapor is below the dew point; for it to be **effective** it is necessary to have at least a slight super-saturation of vapor and the presence of condensation centers (ions, aerosols, etc.). Just at a small super-saturation the sign of electric charge plays an important role: condensation on negative ions is much more effective than on positive ones (Wilson, Rusanov).

Dimensions of tiers, their number, the spacing between them, and the height of the upper and lower tiers are determined by specific weather conditions and the intended purpose (artificial rainfall, ventilation, etc.).

Assembling of the tiers is carried on the ground. Frame is mounted and attached to the ropes, emitters-spokes system is pulled on and balloons are fastened to the frame. Emitters are made of the same metallized film as balloons; the film is cut to have a fringe-like form which reduces the radius of emitter curvature. Since the thickness of metallized layer is of the order of few microns the long sides of film strips serve as blade emitters and their corners as a point one.

To adjust the lifting force under conditions of real operation the balloons are filled with a gas lighter than air starting at the top one and the tiers are launched in turn. Gas amount for each succeeding tier is chosen so that the total lifting force remains roughly constant. After balancing, the tiers are attached with ropes flat to the ground to minimize their windage.

To start the operation the tier attachments to the ground are released starting from the top one and the tiers are launched in turn. During the **launch, descent, so as during all necessary adjustment and installation works the whole device must be well grounded electrically.**

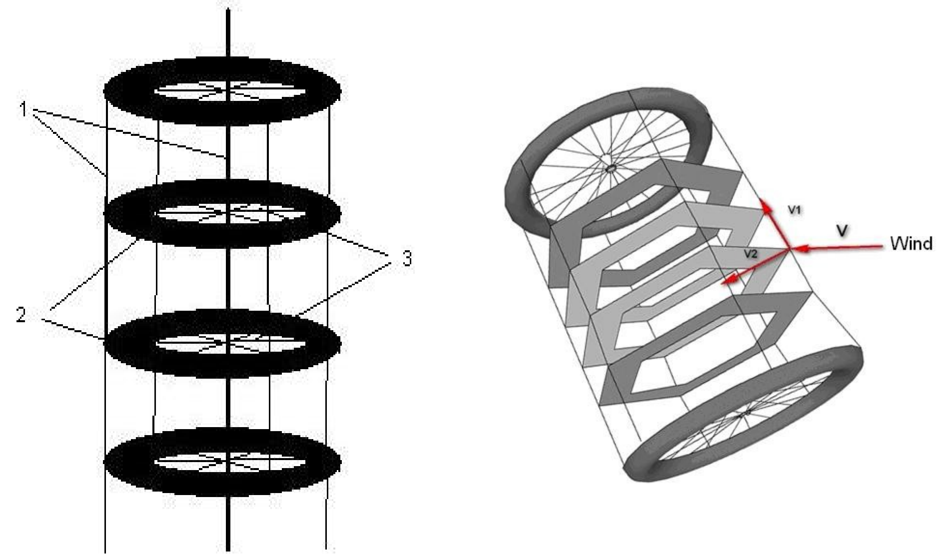

Fig. 4. Possible scheme of the tiered device HELIATOR.

Left *- a simple tori system: 1 – the cables, one of the cables is grounded to Earth; as the electric current is small no large conductor cross-section is required; 2 – the blackened balloons with a gas filling (film tubes made of metalized Mylar/Dacron); 3 – electrically grounded conductive frame in the shape of a bicycle wheel rim with spokes-emitters.* ***Right*** *– the version with additional four heating surfaces between the balloons. The vector force decomposition is shown for a horizontal wind interacting with balloon garland: the component V1 accelerates the upward flow while the component V2 tilts the whole device. Additional surfaces may also be made in the form of tori to improve aerodynamic stability of the system.*

6. Quantitative estimates

Weight. Assume the cross section diameter of a single tube being 3 m and the diameter of a tier 20 m, the vertical distance between the carrying tori is 100 m, and three additional surfaces are attached to the cables (Fig. 3, 4). The volume of a torus is 444 m^3, the lifting force of a full balloon with helium filling is about 470 kg (an additional force ~ 25 kg is present because of the balloon itself and the gas inside being heated by ≥ 20° C above the ambient temperature). The area of the torus surface is 592 m^2. The weight of the shell together with additional surfaces with 800 m^2 area is 28 kg (if the specific weight of Mylar film is 20 g/m^2).

The weight of 600 m long rope is 10 kg (i.e. 6 Kevlar cables are anticipated with a 4.5 mm diameter, the linear weight of 1.6 kg/100 m, the break load of 1900 kg); the weight of 20 spokes-wires of a 1 mm diameter is 3 kg (the break load is 1.3 T); the weight of the hard profile plastic rim is 30 kg.

The total weight of a tier is about 70 kg, i.e. for a neutral buoyancy the torus requires only 0.15 - 0.2 of its volume to be filled with gas, and remains in the form of a flat, 4.5 m wide ring with low resistance to horizontal wind and the optimum area of heating surface. The balloon may consist of separate sections to ease its transport and to prevent the inner flow of the gas when it is tilted.

Sidewind. The large diameter of the upward air flow (2-3 times above the tier diameter in the Fig. 3), the self-focusing of the ring torch and the tilt of whole installation because of its windage (Fig. 4) prevent any blowing-out of the updraft from the system with horizontal wind. The slope of installation axis depends on the relation between the drag force and the lift force with account to updraft. For the 5 m/s horizontal wind the drag force is about 1.5kg/m^2 and varies proportionally to the square of its speed. If the lift force is selected correctly the tilt of the axis follows automatically to the tilt of convection torch and the blowing-out of the latter does not occur. Moreover, because of the tilt the component of the wind velocity which is parallel to installation axis accelerates additionally the updraft. If the horizontal wind becomes stronger (which is a destruction sign of anticyclone) the system must be lowered. The days with wind stronger than 5 m/s in Moscow region are quite rare and their sum number during the May – August period of the years 2009 - 2012 is below 10 (http://www.gismeteo.ru/).

Heating. The area of illuminated surface of a balloon on a single tier depends on position of the Sun and in average amounts to 250m^2. With an additional 800m^2 surface the absorbed solar power occurs about 900-1000 kWt at each tier with account of shadows. With the mean updraft velocity of 2 m/s (which is greater inside a tier; see Fig.3) this power ensures an air heating up to 2.4^o C at each tier (with the 1m/s velocity the heating will be 4.3^o C). If to assume the cooling of the ascending air on 0.5^o C between the tiers because of its adiabatic expansion and the turbulent mixing with ambient air then after 10th tier the updraft may overcome a 20^o C temperature inversion, even without any account to inertia of ascending flow. The temperatures differences meet in reality are lower. The 0.5^o C cooling supposes a large, 15-20% admixture of the ambient air through the side surface of updraft which is **inversely proportional to tier diameter**.

Performance. Accordingly to calculations (Fig. 3), the updraft diameter is about 50 m; the area of its cross-section is about 2000 m^2. The average velocity of ascending flow increases correspondingly to its heating at succeeding tiers, and at the outlet of the last tier at the level of condensation is above 10 m/s, i.e. 20,000 m^3 of air with absolute humidity about 15 - 30 g/m^3 passes per second. Assuming the water condensation level of 5 g/m^3 (which is average water content of summer cumulonimbus clouds) the liquid water production occurs about 100kg per second or 360 tones per hour only due to updraft heated with HELIATOR.

Formation of a cumulus cloud. At the outlet of the last tier the heated air continues to rise up because of inertia, spreads in horizontal direction and cools gradually down to the point of dew. The condensation of water vapor into a fog begins with simultaneous volumetric air heating in central part of the cloud. At the very periphery of cloud an admixture of the ambient dry air causes partial evaporation of the fog with formation of the cold downward air streams. Condensation of 5g of water vapor heats a cubic meter of the air on 10^{o} C. This is a very intensive heating which is dispersed over the hundreds and thousands of meters in the height. The ascending air flows which rises with acceleration draw away the surviving vapor to the altitude were the temperature gradually become lower, and a smaller absolute humidity is sufficient for saturation so the remnant vapor may condense additionally, and so on. In a dynamic equilibrium between condensation and evaporation at the altitude of zero isotherms about 5-15 g/m^3 i.e. 100-300 kg/s of water vapor may condense inside the updraft volume. If to accept a lower estimation limit of 100 kg/s the power of thermal flux inside the cloud occurs about 60 Mcal/s or 250 MWt while the solar power used for updraft heating (which is proportional to the number of tiers) amounts to 10-20 MWt for a 10-20 tiers installation.

Hence, **initiation of water vapor condensation inside the near-ground air raised up with HELIATOR triggers a self-sustaining convection process whose power surpass significantly the power of solar heating.**

Summary. Large power released in condensation accelerates additionally the ascending flow which starts near the ground due to upward traction in a cumulus cloud which increases up to several times its effective diameter and performance, strengthens its sustainability to horizontal wind and aids to overcome the detaining anticyclone layers. The accelerated updraft of the near-ground air starts to rotate anti-clockwise, like a cyclone, which improve further its stability (mini-cyclone).

Beside the effects described above there exists a contribution into the lifting force of the ascending flow which is difficult to estimate and which is caused by the heating of the conductor and emitter elements, by the thermal flux from electron affinity to oxygen and water molecules at the enrichment of the updraft air with negative ions, by the positive humidity difference between the near-ground and high levels of the air.

All estimates are made at a minimum.

It is seen from estimations presented that with exception of tier diameter no characteristic parameter is decisive enough and may be varied in a sufficiently wide limits. **The critical diameter of the tier** depends on weather conditions and must be selected experimentally to ensure initiation of a self-sustaining condensation process.

7. Conclusion

The problem of the fresh water supply and the worsening of other environmental problems both all around the world and at the relatively safe middle latitudes urgently require a solution which is recognized at the UN level.

The HELIATOR system is designed just exactly for this purpose. It is destined to stimulate sedimentation of water precipitation with the aim to delay the environmental degradation in dry conditions. It may be brought into operation (i.e. the balloon garland may be raised in the air) in accordance with the need and turned off (lowered down) afterwards as needed.

The main distinguishing features of the method proposed are its friendliness to the environment, the low cost and simplicity of construction, the reusability, the portability, the lack of any external consumables and energy supplies. Complete powering of operation is provided by the solar radiation and the electric field of the Earth.

The multi-layered heating of an air updraft in the atmosphere differs principally from any of the ground-based methods. It provides possibility to sustain a controllable excess of the updraft temperature above the temperature of surrounding air and consequently to regulate its lifting force at every height of ascend. The use of a garland of tethered aerostats forms a flexible central trunk of the updraft and provides it with the negatively charged ions which become the centers of future condensation of the water vapor. The flexible trunk follows automatically to any horizontal wind variations at different heights and prevents the blow-off of heated air from the HELIATOR system.

Using the fresh water from land sources such as lakes and rivers creates a competition between the industry and agriculture. Since 1000 tons of water are necessary to produce one ton of $200 worth wheat or to ensure a $14000 growth of industrial production the industry usually wins the fight for water (Brown L. et al, 1999). In this sense the precipitation water is mainly used for the purposes of ecology and agriculture.

The artificially induced air updraft carries away and dissipates the heat and pollution from the lower atmosphere resulting in a rain, ventilation and cooling of the air.

Simultaneous operation of a multitude of installations of the proposed type may facilitate speeding of the water circulation cycle. A number of such installations may lower the energy stock preserved in the atmosphere in the forms of a heat and moisture and hence diminish the risk of catastrophic atmospheric phenomena safely. The oscillations of the weather pendulum "drought – flood" may effectively be damped.

A placement of meteorological instruments on the tiers of multi-layer system allows to effectively exploring the dynamics of the atmospheric processes under controlled conditions.

It should be stressed again that all of the required power for this installation functioning is provided exclusively by the solar radiation and the electric field of the Earth.

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