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PREVENTIVE JET FORCING AND THE ALAZANI VALLEY HAIL SUPPRESSION PROBLEM

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Summary: *The Alazani Valley hail problem is considered within the framework of the Preventive Jet Forcing concept based on the modification of energy flows forming convective clouds. The system with natural meteotron (Mount Tsivi) is considered. The regional wind through the orographic lift (together with solar thermal forcing) triggers a strong enough convective cloud and then delivers it to the valley. The concept provides for limiting the concentration of instability energy in the cloud by artificial time shift in its triggering and delivery using installed on Mount Tsivi decommissioned jet engine (meteotron). A comparison is made of the efficiency of using a jet engine in the arid zone, in the Alazani Valley, and on the Tsivi Mountain. The solar thermal forcing capacity of Tsivi mountain is estimated.*

Key words*: preventive jet forcing, meteotron, orographic lift, solar thermal forcing.*

Introduction. In [1], an attempt was made to draw attention to an alternative approach to the problem of severe convective storm by modifying the energy flows forming convective clouds. The preventive jet forcing concept (the PJF concept) is aimed at limiting the concentration of energy in a single cloud, leading to the most dangerous development, by artificially preventive forcing of convective clouds in those places and at those points of time that will allow a relatively safe discharge of the accumulated convective available potential energy (CAPE) using for forcing clouds of jet engines, also called meteotrons [2].

In [3], the problem was considered in the context of the role of the jet engine placement height in increasing the efficiency of a convective cloud forcing.

A terminological update of the research line was also carried out.

Starting from [1], the role of the main keyword was assigned to the term "restratification", which was used at that time in the Soviet scientific literature. In relation to the layers of the atmosphere in the modern English-language scientific literature, this term is usually not used (sometimes it is used in relation to the layers of the sea).As convective cloud forcing inevitably leads to the very "restratification", it becomes more appropriate to bring to the fore the keyword reflecting the principle of artificial forcing: "preventive jet forcing". Accordingly, “the anticipatory restratification” evolved into “the Preventive Jet Forcing”.

Methods. The study includes consideration of the main features of the qualitative model of the hail in the Alazani Valley, the model of the system with a natural meteotron (the SNM model), taking into account the formation of a primary cloud on Mount Tsivi as a result of the orographic lift of the westerly wind and its further delivery to the valley by the same wind.

The PJF concept [1] is based on the well-known idea of the pre-cloud atmosphere as an unstable layer of humid air under the capping inversion, where the latter prevents the CAPE discharge. As soon as convective currents manage to break through the first channel through capping inversion, the latter begins to assist to the cloud in collecting the CAPE from the largest possible area, continuing to close the convection path in the rest of the territory. Since the maximum power of a convective cloud depends on the CAPE it has mastered, this is the right path to a strong convective storm, including hail

For the case of a large plain, the prevention of such a development is proposed by the preventive discharge of the accumulated CAPE by several convective clouds, artificially launched at various points of the protected area at distances safe for cloud merging using meteotrons (jet engines) [2].

Initially the meteotron was used without much success to make it rain in arid zones [2]. As shown below the task becomes much easier when implementing the PJF concept.

The SNM model refers to the implementation of the PJF concept in valleys with adjacent ridges. In particular, hail in the Alazani Valley is considered to be the result of a "lucky" correlation of the formation time of the primary cloud on Mount Tsivi with the build-up of CAPE in the valley. Finally, due to this correlation, the cloud arrives in the valley when a sufficiently large amount of CAPE has already accumulated to ensure the intensive development of the cloud, up to severe hail.

To break this "luck" is proposed to ensure the early arrival of cloud when the accumulated CAPE is still insufficient to amplify it to hail and the end result is rain. This task can be performed by a jet engine placed on the top of Tsivi, which in this case should only accelerate the forcing convective cloud formation by orographic lift and solar thermal forcing, which can be a low energy-consuming action.

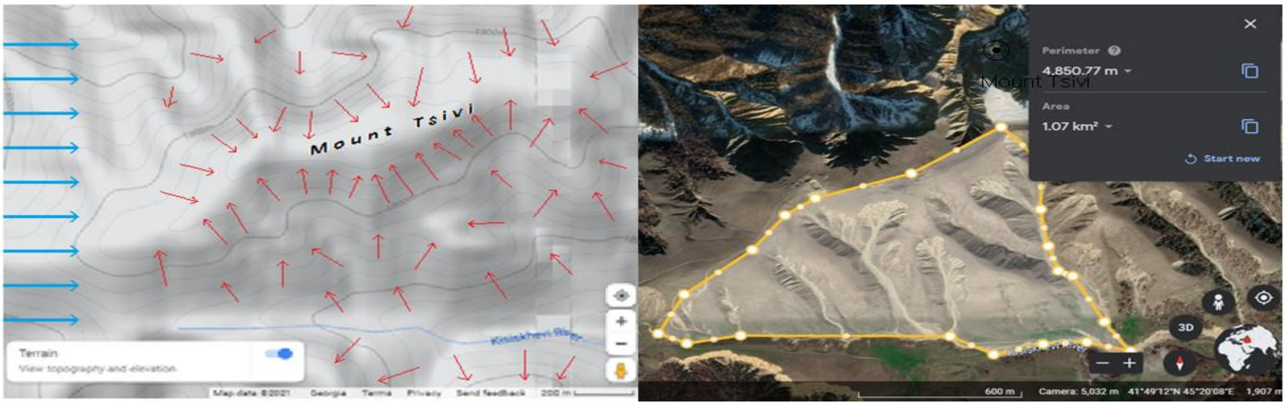
As a result, the anticipatory appearance of the convective cloud in the valley is ensured, when the losses from its further development will be minimal.

In addition, since, compared to many of the studied mountains (eg, Mount Catalina, Arizona, USA [4]), Mount Tsivi has a very small area from where anabatic winds can deliver solar heat to the summit, it is also interesting to estimate its solar thermal forcing capacity and even compare it with the potential heat dissipation by the jet engine.

In general, one should also emphasize the universal nature of the principle of instability energy discharge distributed in time and space, applicable to prevent or mitigate almost all severe meteorological phenomena. The main difficulty, of course, lies in the effective implementation of the principle.

Results and discussion. In order to first clarify the level of the possible contribution of a jet engine in the thermal forcing in the specific conditions of Mount Tsivi, we begin with an assessment of its natural solar thermal forcing capacity. To avoid overestimating the role of the jet engine, when determining the required for the assessment parameters, approximations always are made in the direction of overestimating the natural solar forcing capacity,

The relief map and top view of Mount Tsivi are shown in Fig. 1.



a) b)

Fig .1. The zone of Mount Tsivi: a) relief map of the zone according to Google Map; b) top view of the zone via Google Earth showing the portion of the southern slope of the mountain involved in solar thermal forcing.

As follows from Fig. 1a, the summit of Tsivi is a narrow, almost rectangular strip about 100×800 m^2 from west to east, collecting anabatic winds (red arrows) from the southern and northern slopes.

The relief of the western slope is very convenient for the development of the orographic ascent of the westerly wind (blue arrows).

At the same time, in contrast to the southern and northern slopes, the western slope contributes very little to the lateral concentration of solar heat by anabatic winds at the summit (only a narrow part of the front of the anabatic wind will fall directly to the summit), which diminishes the significance of this slope in terms of building up the energy base for solar thermal forcing (our consideration covers only the period of maturation of the situation).

However, an indirect mechanism remains in force - the transfer of solar heat from the anabatic flows of the western slope by joining the anabatic flows of the southern and northern slopes.

As for the eastern slope, it is excluded from the focusing of the anabatic winds at the summit for the simple reason: the anabatic wind would have to overcome the much more powerful westerly wind.

We begin the assessment of the solar heat inflow at noon on a summer day from the southern slope, the three boundaries of which are clearly defined: the summit itself, the western watershed and the Kisiskhevi River. We slightly move the eastern border to the zone where the anabatic wind has to partially blow against the main wind, thereby somewhat overestimating the active area of the southern slope (Fig. 1b)

The projected area of the slope and its average incline are determined using Google Earth and the area of the slope itself is calculated (1.12 km^2). Further, we use the value of the maximum heat flow from the surface of the earth to the air at noon on a summer day according to the data for Mount Catalina [4] (200 W / m^2) located 10 degrees south of Mount Tsivi, again slightly overestimating the thermal power of the slope.

Next, the total heat flux from the slope to the air (224 MW), determined from these data, is considered to be completely supplied to the summit, although a significant part of it is carried away by the main wind, and this is not considered an overestimate: in this way we take into account the above heat brought by the anabatic flows from the western slope.

Having determined the contribution of the southern slope to solar thermal forcing on Mount Tsivi, we proceed to a comparative assessment of the thermal capacity of the northern slope, which, naturally, is inferior to the southern one in terms of heat flow from the surface into the air, but is practically not limited by the length of the slope.

However, as our analysis shows, despite its much greater extent, the capacity of the northern slope is clearly less than the capacity that we have already attributed to the southern slope. The fact is that due to the influence of the main wind, only slope section close to the summit can participate in the thermal forcing. At a distance from the summit, for example, more than 800 m, with the same velocities of the main and anabatic winds, the overheated particle will most likely be carried away by the main wind before reaching the summit. At that, in reality, the speed of the main wind is always much higher.

Thus, taking into account the exclusion of the eastern slope and the adaptation of solar heat received on the western slope by the anabatic flows of the southern and northern slopes, we can attribute the thermal capacity of the southern slope to the northern slope (overstating its value) and estimate the Mount Tsivi full solar thermal forcing capacity at 448 MW (roughly 500 MW).

At the same time, according to the reference data on the specific fuel consumption of various aircraft, heat dissipation by a passenger jet engine ranges from 1 to 30 MW. Thus, the meteotron cannot make a tangible contribution to thermal forcing even in the specific conditions of Mount Tsivi, with very little surface area for the development of anabatic flows.

Having decided on the thermal forcing, let's move on to a comparative consideration of the conditions of the primary, main function of the jet engine, dynamic forcing of convective cloud.

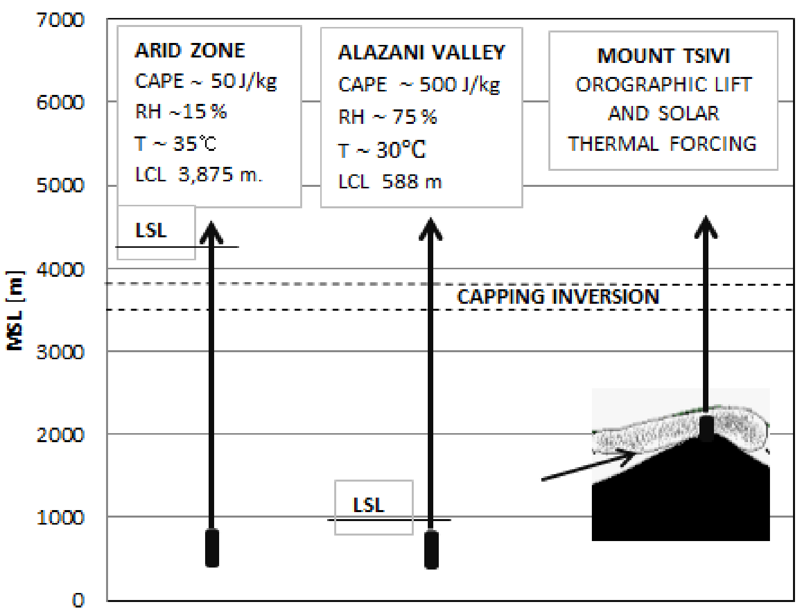


Fig. 2. The comparison of a jet engine functioning in arid area, in Alazani Valley, and on Mount Tsivi.

The comparison of a jet engine functioning features in arid area, in Alazani Valley and on Mount Tsivi (Fig. 2) allows us to draw some interesting conclusions.

The operating conditions of the first two jet engines (in arid zone and in Alazani Valley) coincide only by their location above sea level (400 MSL). Otherwise, strongly differing initial air parameters (shown in Fig. 2) lead to sharply different potential development patterns, which is reflected in the values of the Lifting Condensation Level (LCL). If in the Alazani Valley the jet produced by the engine almost instantly turns on powerful latent condensation heat release, then in the arid zone such a jet should rise and break through the capping inversion on its own, which, accordingly, will dramatically affect the required power of the jet engine.

The next sharp decrease in the required power of the jet engine looms at the transition from the valley to Mount Tsivi.

There, in the supposed operating time interval (10-00 - 17-00), the jet engine is not only close to capping inversion, but from the very beginning is in non-convective clouds and only has to assist the orographic lift and solar thermal in anticipatory forcing of a convective cloud.

The part of these conclusions is indirectly confirmed by the long-term statistics of hail in the valley [5], which records an absolute minority of the cases of hail due to the formation of intra-massive clouds. Another part also indirectly is confirmed by approximate analysis [3].

Not excluded, it will be possible to speak of a decrease in the required power of the jet engine relative to the arid zone by one or two orders of magnitude, which would open up the prospect of effective implementation of the concept.

Conclusion. The first important step towards the possible implementation of the looming optimistic perspective should be a detailed analytical and numerical modeling of the corresponding processes.

First of all, this concerns the system with natural meteotron, in particular, the Alazani Valley - Tsivi Mountain system.

Of particular interest is modeling of orographic lift and solar thermal forcing in combination with dynamic forcing by the jet engine, with the subsequent inclusion into unified model of the Alazani Valley - Tsivi Mountain system.

If preliminary expectations are confirmed, the next step should be a large-scale field experiment.

It is also necessary to start modeling the system of the centralized optimal control of the network of meteotrons covering a large region including a short-term forecast of the regional situation.

Finally, given that global warming only promises continuous increase in humidity, CAPE, and the strength of hail and tornadoes [6], we can set our doubts about PJF concept aside for a moment and look to the future with over-optimism.

Admitting instantly the ideal success of the concept (functional, economic, and ecological), one can imagine a vast region covered by a network of meteotrons (located, where possible, on hills and mountains), with a unified control system that allows redistributing (within certain limits) precipitation in space and time, to reduce the CAPE and humidity in places of expected hail, tornado, hurricane or cold front.

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