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EVALUATION OF THE EFFECT OF THE REDISTRIBUTION OF PRECIPITATION BY THE METHOD OF THE CLIMATIC AVERAGE

Gekkieva S.

Federal State Budgetary Institution «High-Mountain Geophysical Institute»,
Nalchik, The Russian Federation
sgekkieva@list.ru

Summary: *Precipitation has significant natural variations in time and space. The calculation of the probability of increasing or decreasing the amount of precipitation against the background of their natural variability as a result of work on active influences is not an easy task. A statistical assessment of the effect of the redistribution of precipitation in the protected and control areas was carried out using the climatic average method*

Key words: *active effects, artificial increase in precipitation, redistribution of precipitation, climatic average method*

Weather conditions often deviate from "normal" and people are forced to look for ways to address the targeted impact on the weather, depending on the tasks that need to be addressed. In particular, work is underway on the practical implementation of the method of active effects on clouds in order to increase (reduce) the amount of precipitation. The purpose of such works is to create more comfortable living conditions for large Metropolitan areas and solve the water shortage for the needs of the agricultural sector. Many scientists argue that most of the world's population will lack fresh water in the near future. Even in Russia, a feature of which is its high availability of water resources (average annual flow-4300 cubic km), many agricultural regions belong to the zone of risky agriculture with an acute shortage of water. Therefore, the problem of water scarcity is urgent, and scientists from all over the world are working to solve it [1].

However, the uncertainty in determining the effectiveness of artificial rain, has not yet received significant development for some reasons. One of them is that it is not yet possible to give a definite satisfactory answer. There is much doubt about the impact that artificial rain in one area can have on neighboring areas. What will happen to the water supply in an area if the clouds moving towards it are artificially dewatered in advance?

It should be noted that in a number of works, it is suggested that the increase in precipitation over a certain area should be accompanied by a decrease in another area, located relative to the first in the wind, that is, that active effects for the purpose of artificial increase in precipitation do not lead to an absolute increase in precipitation, but to some of their redistribution over the area. There are works in which the opinion is expressed that there will be no such decrease in precipitation. Therefore, the assessment of the impact results is currently carried out by statistical methods [2]. On the basis of statistical methods, a methodology for assessing the effect of precipitation redistribution has been developed. This assessment boils down to the fact that it is necessary to determine whether there is a redistribution effect at all and what is its magnitude?

The main contribution to the amount and intensity of precipitation in the North Caucasus, in particular, in the Stavropol territory is made by wet frontal processes moving from West to East. As we move to the East and the transformation of wet air masses on the Stavropol upland decreases their moisture content and increases the aridity of the territories. In the same direction, the amount of precipitation decreases and their natural fluctuation increases, so in the Stavropol territory, work was carried out for a long time to artificially increase precipitation [3]. However, the impact of these works on the regime of precipitation in neighboring areas remained uncertain. To date, data on precipitation in protected and control areas have been collected, which allows for preliminary statistical analysis using a single methodology. As a control of the territories was taken: Mineralnye Vody, Kislovodsk, Karachaevsk. Adjacent territories: Nalchik, Cool, Terek, Kamennomostskoye, Mozdok, Yuzhno-Sukhokumsk, Terek-Mekteb, Kochubey. On the map of the North Caucasus (figure 1) you can see their geographical location.

Fig. 1- Map of the North Caucasus

Protected and control areas are selected so that they meet the basic requirements for further comparison. The main requirements include the following:

- similar physical and geographical characteristics;
- close to the area of impact size, close to the density of the terrestrial sedimentary network, approximately the same length of the series of observations of precipitation;
- time-stable correlation of precipitation on control areas and protected area for the longest possible number of years before the onset of impacts.

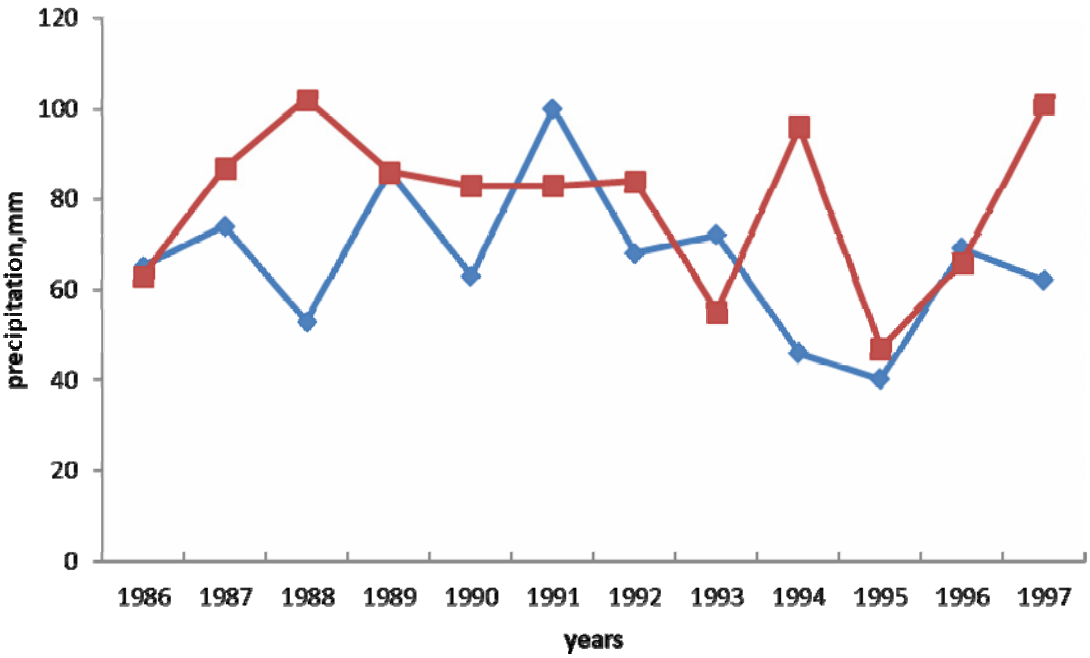

Fig. 2 – time course of precipitation (may-august) in the control and adjacent territory, row 1(blue) – control territory, 2(red) – adjacent territory

Local and regional changes in the nature of precipitation variability depend largely on the nature of atmospheric circulation variability. Some of these observed fluctuations are related to global climate change. This makes some regions wetter and some, often nearby, drier, making it more difficult to assess the effect of precipitation redistribution through artificial precipitation augmentation work.

Evaluation of the effect of redistribution in artificial increase in precipitation using the climatic average.

In accordance with the method of climatic average, deviations of precipitation values from their norms in the control and adjacent territories are compared. Works on active influences for the purpose of artificial increase of precipitation in Stavropol Krai were begun in 1986, in connection with what the natural mode of precipitation was broken. Therefore, the calculation period was chosen from this year. The heterogeneity of the intensity and spatial distribution of spring-summer precipitation, as well as the heterogeneity of the sedimentary network in the study areas lead to the need for space-time averaging of precipitation. Precipitation averaging can significantly reduce the coefficient of variation of precipitation. The data on the distribution of precipitation for may – august in the study area for the period of active impacts from 1986 to 1997 are presented in [4].

$$Y_{at_c} = \frac{X_{ct} \times \bar{Y}_{at}}{\bar{X}_{ct}} \quad (1)$$

$Y_{at_c}, X_{ct}, \bar{Y}_{at}, \bar{X}_{ct}$ – accordingly, the estimated amount of precipitation in the adjacent territory in the absence of exposure, rainfall on site, the actual amount of precipitation in the control area, the rainfall in the control area.

Table 1– Data on additional precipitation over the years of active impacts, obtained by the method of climatic mean

years	X(mm)	Y(mm)	Y_c (mm)	ΔY(mm)
1986	65,2	63,0	85,0	-22,0
1987	74.3	86,8	97,0	-10,2
1988	53,2	102,1	69,0	33,0
1989	86,0	86,0	112,0	-26,0
1990	62,8	82,6	81,6	1,00
1991	100,3	82,7	130,0	-47,0
1992	68,2	84,3	89,0	-4,70
1993	71,8	54,8	93,0	-38,2
1994	45,5	95,8	59,0	36,8
1995	40,3	47,3	52,0	-4,70
1996	68,5	66,0	89,0	-23,0
1997	61,4	100,8	80,0	20,8

To assess the significance of differences in average values of precipitation ratios, as a percentage of the norm in the control and adjacent areas for each year, we use the student's criterion [5]:

$$\text{T}_{obs} = \frac{(\bar{X}_{ct} - \bar{Y}_{at})}{\sqrt{(n_n - 1)\text{S}^2 + (n_к - 1)\text{S}_к^2}} \times \sqrt{\frac{n_c n_a (n_a + n_c - 2)}{n_a + c}} \quad (2)$$

According to the level of significance of α, the null hypothesis H_0: $E(X_{ct}) = E(Y_{at})$ on the equality of the two means is tested with the competing hypothesis H_1:$E(X_{ct}) \neq E(Y_{ct})$. From the table of the student's distribution by the level of significance α and the number of degrees of freedom $к = к = n_{at} + n_{ct} - 2$ we find the critical point $t_{cr}(α,к)$. If $T_{obs} < T_{cr}$, then there is no reason to reject the null hypothesis. In this case, the difference between the mean X_{ct} and Y_{at} in the control and adjacent areas is not significant (at the level of significance α). If $T_{obs} > T_{ct}$, we reject the null hypothesis and accept the competing hypothesis.

By the formula (2) we find T_{obs} = 2,3. According to the student's distribution table, we find T_{ct} (0.05; 20) = 2.08. $T_{obs} > T_{ct}$, therefore reject the null and accept the competing hypothesis. That is, the difference between the average X_{ct} and Y_{at} in the control and adjacent areas is significant at a significance level of 5%.

In order to analyze the effect of the impact for each individual year with AB, it is necessary to know to which year it refers-with excess or, conversely, with a deficit of precipitation. To find out the humidity (aridity) of the year, we use the method of integral curves, where deviations from the norm K have a positive sign, i.e. corresponds to the year with excess precipitation, and the area with a negative value to the period with a shortage of precipitation.

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$$K = \frac{X_i}{\bar{X}} - 1 \quad (3)$$

where X_i is the monthly rainfall for each year, $\bar{X}$ is the monthly rainfall.

Table 3 – Calculations of coefficient K for the adjacent territory (Nalchik)

years	X (mm)	K
1986	63,0	- 0,3
1987	86,8	0,02
1988	102,1	0,2
1989	86,0	0,01
1990	82,6	-0,03
1991	82,7	-0,03
1992	84,3	-0,01
1993	54,8	-0,4
1994	95,8	0,12
1995	47,3	-0,4
1996	66,0	-0,22
1997	100,8	0,18

From table 3 it is evident that the year of drought include: 1986, 1993, 1995 – 1997; wet years: 1988, 1997. The monthly rainfall for Nalchik is $\bar{X}$ = 85 mm.

Thus, taking into account the calculated data given in table 2, we conclude that the greatest increase in precipitation in the surrounding area occurs in wet years (1987,1997), and the greatest decrease in years with a shortage of moisture (1986, 1989, 1991, 1993, 1996). The greatest effect of precipitation redistribution is observed in the years when natural precipitation is most variable. That is, in years with abundant moisture, there is an even greater increase in precipitation, and, conversely, in years with a lack of moisture-an even greater decrease in precipitation, which causes in both cases quite undesirable consequences, whether it is a drought or too rainy, wet year.

The other side of this question is economic. Should we try to cause precipitation artificially if there is not enough rain and agricultural areas are affected? Of course, Yes, if it rains heavily, and we get high yields of agricultural crops. The cost of cloud seeding per hectare is usually small compared to the cost of crops on the same area. However, if cloud seeding has not led to an increase in precipitation, then minor costs may seem too high.

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