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Atmospheric precipitation as a source for the formation of surface water resources of the desert zone

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Abstract. The purpose of this article is to scientifically substantiate the metrological aspects of the possible volumes of surface runoff throughout its entire territory, which could be used in the interests of agricultural production. The article discusses the monthly norms of atmospheric precipitation at the meteorological stations of the Kyzyl Kum desert. It has been determined that in the Kyzyl Kum desert up to 75% of atmospheric precipitation falls in liquid form. Accordingly, the share of solid and mixed precipitation accounts for about 25%, and this ratio regularly changes with the movement from north to south. At present, the conditions for the formation and regularities of the spatial distribution of surface water resources of the Kyzyl Kum desert are unknown and, in the author's opinion, it is economically inexpedient to neglect them, especially in dry years. The study used the most developed method of correlation functions to estimate the possible error in extrapolating the sum of atmospheric precipitation to a given area, but with respect to the entire set of meteorological stations available in the Kyzyl Kum desert. The results of the study showed a high stability of the ratios of monthly and maximum daily amounts of atmospheric precipitation. This stability takes place both in relation to the entire spring time and throughout the entire area of the Kyzyl Kum desert. Such stability and calculated ratios make it possible to roughly determine the daily precipitation amount, having only data on their monthly amount.

1. Introduction

The importance of the Kyzylkum desert in the economy of Uzbekistan is great, since the territory of the Kyzylkum desert has more than 1.5 million hectares of land suitable for plant growing. Here, the main limiting factor in the cultivation of agricultural crops is the lack of water resources, and the resources of the rivers of Uzbekistan, as well as the water resources coming to the territory of Uzbekistan from neighboring states are almost completely exhausted.

Precipitation is measured at meteorological stations and these measurements are accompanied by systematic and random errors.

2. Information

Monthly norms of atmospheric precipitation for the meteorological stations of the Kyzyl Kum desert (table 1) are calculated from actual series with corrections for instrumental errors already introduced.

Table 1. Average monthly and average annual precipitation (mm) for meteorological stations of the Kyzyl Kum desert.

Month	Meteorological stations								
	Akbaytal	Chaban kazgan	Kulkudook	Bazau buy	Tamdy	Masha kuduk	Karakul	Ayakagitma	Jan gels
I	18	16	15	9	13	14	17	17	16
II	17	14	18	11	16	17	18	16	18
III	29	24	27	20	20	22	27	24	25
IY	23	19	24	14	24	24	22	22	23
Y	13	11	12	8	13	12	8	12	9
YI	3	2	4	2	4	3	2	2	2
YII	2	1	2	1	2	1	0	1	1
YIII	0	0	1	0	1	0	0	0	0
IX	1	0	1	0	1	0	0	0	0
X	4	2	5	2	6	5	4	5	5
XI	9	7	8	8	10	9	11	9	10
XII	15	14	14	10	14	13	14	14	14
Year	125	110	131	85	124	120	123	122	129

Note: According to the Scientific Research Hydrometeorological Institute of the Republic of Uzbekistan (NIGMI)

At the same time, it is easy to notice the almost identical intra-annual distribution of precipitation for all stations, which is characterized by the following features:

1. The greatest amount of precipitation (46-49% of the annual amount) falls in the spring, and of the spring months, the wettest is March.
2. In the summer months, the amount of precipitation is negligible (no more than 4 mm/month.)
3. The second maximum precipitation is observed in the autumn-winter period, when up to 35% of the annual amount falls.

3. Methodology

In our case, the probable error in estimating the mean monthly total precipitation (ε) is directly proportional to the coefficient of variation of precipitation and inversely proportional to the duration of observations, i.e.

$$\varepsilon = \frac{C_V}{\sqrt{N}} \ , \qquad (1)$$

Where: C_V average annual relative air humidity; N - number of years of observations.

In this case, we will use the most developed method of correlation functions to estimate the possible error in extrapolating the sum of atmospheric precipitation to a given area, but in relation to the entire set of meteorological stations available in the Kyzyl Kum desert. As for the precipitation layer in relation to each of the identified latitudinal zones, then for their assessment we use the data in table 1.

Thus, the following results were obtained (table 2).

Table 2. Average monthly and average annual precipitation (mm) for latitudinal zones of the Kyzyl Kum desert.

Month	Latitude zone		
	North	Center	South
January	16	12	17
February	17	14	18
March	27	22	24
April	22	21	22

May	12	11	10
June	4	3	2
July	2	1	1
August	0	0	0
September	1	0	0
October	4	4	5
November	8	9	10
December	14	12	14
Year	127	107	124

Note: Author's research.

To calculate the monthly sums of atmospheric precipitation in a probabilistic plan, an empirical formula was used:

$$\Pi = \frac{m - 0.3}{n + 04}, \qquad (2)$$

Where: Π – provision of the amount of precipitation per month, %; *m* - ordinal number in the descending series of precipitation; *n* - the number of members of the series.

Calculation according to formula 2 for three spring months and three latitudinal zones shows the possible amplitude of fluctuations in monthly sums of atmospheric precipitation in time.

The data in table 3 indicate that atmospheric precipitation with a small layer of rain undoubtedly prevails in the Kyzyl Kum desert. Indeed, the gradation of precipitation from 1 to 5 mm includes from 30.5 to 41.7% of all days with rain, and if in March and April this gradation is maximum, then in relation to May it can be argued that the first two gradations of atmospheric precipitation are approximately equal.

Table 3. Average number of spring days (n) with rains of different layers.

Month	Zone	Rain layer, mm									
		≤ 1		1 – 4.9		5 – 9.9		10 – 19.9		≥ 20	
		n	%	n	%	n	%	n	%	n	%
III	North	2.8	33.3	3.2	38.1	1.4	16.8	0.7	8.3	0.3	3.5
	Center	2.4	33.3	3.0	41.7	1.2	16.7	0.5	6.9	0.1	1.4
	South	2.6	33.3	3.1	39.7	1.3	16.6	0.6	7.8	0.2	2.6
IV	North	2.3	28.3	2.8	34.6	2.2	27.2	0.6	7.4	0.2	2.5
	Center	2.6	33.8	2.8	36.3	1.7	22.2	0.5	6.5	0.1	1.2
	South	2.7	34.4	2.8	35.4	1.8	22.7	0.5	6.3	0.1	1.2
V	North	1.9	30.6	1.8	29.0	1.5	24.3	0.7	11.3	0.3	4.8
	Center	1.9	33.9	1.8	32.1	1.2	21.4	0.5	8.9	0.2	3.7
	South	1.9	32.2	1.8	30.5	1.4	23.7	0.6	10.2	0.2	3.4

Note: Author's research

The data in tables 2 and 3 allow us to make an objective conclusion, according to which the prevailing amount of precipitation in the Kyzylkum desert (65 - 75%) falls in a layer of up to 5 mm. The number of such days in a month ranges from 4 to 5.

First of all, the data in table 6 draw attention to the high stability of the ratios of monthly and maximum daily precipitation amounts. The fluctuations in the X_{month}/X_{day} ratio are only 0.55 - 0.75, which is more than twice the same value for the Belgrade station and is easily explained by the extremely low number of days in a month with high-layer precipitation.

Table 4. Average ratio between monthly amounts of atmospheric precipitation (X_{month}) and their maximum daily layer (X_{day}).

Month	Zone	X_{month}	X_{day}	X_{day}/X_{month}
March	North	27	16	0.59
	Center	22	11	0.50
	South	24	14	0.58
April	North	22	15	0.68
	Center	21	13	0.61
	South	22	14	0.63
May	North	12	8	0.66
	Center	11	6	0.55
	South	10	6	0.60

Note: Author's research

To confirm the above, the calculation of the correlation coefficients between X_{month} and X_{day} was performed, which, as it turned out, also vary within relatively small limits (0.61-0.82). Thus, it can now be argued that the share of the contribution of the maximum daily amounts to the formation of monthly precipitation is 37 - 67%.

To assess the statistical homogeneity of the series of observations, the χ^2 goodness of fit test was used, an important advantage of which is that it can be applied to empirical data with different distribution laws [8]. The agreement criterion was calculated using the formula:

$$\chi^2 = \text{н}_1\text{н}_2 \sum_{i=1}^{L} \frac{1}{m_1 + m_2} \left(\frac{m_1}{n_1} + \frac{m_2}{n_2}\right), \tag{3}$$

where н_1 and н_2 are two independent samples of volumes located in L groups with numbers m, and the initial data were the series of observations for four pairs of meteorological stations located differently with respect to latitudinal zones, absolute heights, and mutual distances.

Since the values of the goodness-of-fit criterion χ^2 according to the distribution table with the probability $\Pi(\chi^2) = 0.05$ [6], in all cases turned out to be higher than the actual value by an average of 10% (12.4 versus 14.0), it was concluded that the series were statistically homogeneous.

The practical use of the apparatus of correlation functions provides for the presence of a known range of distances between meteorological stations, at which precipitation is recorded synchronously and systematically. In our case, the distance between the stations varies from 75 to 405 km (table 5).

Table 5. Matrix of distances (km) between meteorological stations of the Kyzyl Kum desert.

	1	2	3	4	5	6	7	8	9
1	0	225	240	285	270	315	455	380	320
2	-	0	150	225	130	230	405	275	265
3	-	-	0	137	212	300	405	310	245
4	-	-	-	0	175	225	265	200	115
5	-	-	-	-	0	85	250	115	125
6	-	-	-	-	-	0	200	75	160
7	-	-	-	-	-	-	0	175	150
8	-	-	-	-	-	-	-	0	100
9	-	-	-	-	-	-	-	-	0

Note: Author's research. Sequential numbers of meteorological stations see table 1.

As can be seen, the statistical structure of the precipitation field in the selected time intervals is significantly different, and, first of all, attention is drawn to the different intensity of the decrease in the correlation functions with increasing distance. If the correlation radius is L_o, i.e. the distance at which the ordinate of the correlation function y is *e* times is 360 km for March precipitation, then for April L = 210 km, and in May it is reduced to 45 km.

From this, in particular, it follows that in the months under consideration, a different number of meteorological stations is required to estimate (all other things being equal) the average amount of precipitation for a given area, but with the same equally secure error.

4. Findings

The obtained correlation functions have an exponential form, which is in good agreement with previous studies [5,9]. The functions are approximated by an analytical formula of the form:

$$p\,(L) = p\,(0)\,e^{-aL} \tag{4}$$

Where: p (L) is the correlation coefficient at a distance L between meteorological stations, p (0) is the value of the empirical correlation function at $L \approx 0$, determined by the extrapolation method, α is a structural parameter.

From the data in Table 6, one can see very significant differences in the parameters of the correlation functions in relation to different spring months.

Table 6. Parameters of correlation functions of atmospheric precipitation in the Kyzyl Kum desert.

Parameter	March	April	May
X^{avr}, mm	24	22	11
σ mm	17.1	16.1	12.1
p (0)	0.863	0.829	0.751
L_o, km	360	210	45
α	$143\cdot10^{-2}$	$160\cdot10^{-2}$	$750\cdot10^{-3}$

Note: Author's research

5. Results

The results of calculating the errors in estimating the average precipitation layer in a given area, depending on the number of used meteorological stations, are shown in table 7.

The data in table 7 can be used to establish the optimal number of meteorological stations in a given area, necessary to determine the average rainfall with a given error. In this case, one should proceed from the fact of a rapid decrease in the error in estimating the middle layer with an increase in the meteorological stations used for the calculation, as well as with a decrease in the area with the same number of stations.

All other things being equal, the determination of the average over the area of the March layer of atmospheric precipitation for the same area and the same equally secure error in the estimate of the desired value will require a smaller number of meteorological stations than for April and, especially, May precipitation.

Table 7. Absolute (ε ,mm) and relative (P%) error in determining the average over the area (C km2) precipitation depending on the number of meteorological stations (H) evenly distributed over this area.

C	H	March		April		May	
		ε	Π	ε	Π	ε	Π
10	2	6.1	25	6.8	31	5.3	48
	5	4.5	19	5.1	23	3.4	31
	10	1.9	8	2.2	10	1.6	15
50	2	8.4	35	10.1	46	6.7	61
	5	5.5	23	6.4	29	5.4	49

	10	3.4	14	3.7	17	2.7	25
100	2	11.8	49	13.2	60	8.7	79
	5	8.9	37	9.0	41	7.0	64
	10	5.5	23	7.3	33	4.4	40
200	2	15.6	65	16.5	75	10.4	95
	5	13.9	58	14.1	64	8.7	79
	10	10.6	44	11.2	51	7.5	68
300	2	21.1	88	21.7	99	13.1	119
	5	19.1	79	18.0	82	11.1	101
	10	17.0	71	17.2	78	8.8	81

Note: Author's research

The foregoing allows us to conclude that the use of the results of studies of the spatial variability of atmospheric precipitation described in this article seems to be very expedient for any operations with this element on the territory of the Kyzyl Kum desert.

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