

## DETERMINATION OF CHARACTERISTICS MAXIMAL RUNOFF MOUNTAIN RIVERS IN CRIMEA

V. Ovcharuk\* and O. Todorova

Odessa State Environmental University, Ukraine

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### ABSTRACT

This article has been examined maximum runoff of the rivers of the Crimean Mountains. The rivers flow through the western and eastern part of the northern slope Crimean Mountains, and on its southern coast. The largest of them: Belbek, Alma, Salgir, Su-Indol and others. To characterize the maximum runoff of rain floods (the layers of rain floods and maximum discharge of water) on the rivers of the Crimean Mountains were used materials of observations for long-term period (from the beginning of observations to 2010 inclusive) on 54 of streamflow station with using a the so-called «operator» model for maximum runoff formation.

**Key words:** maximum runoff; rain floods; hillslope runoff; karst.

Author Correspondence, e-mail: [valeri.o@mail.ru](mailto:valeri.o@mail.ru); [lenochka.todorova@mail.ru](mailto:lenochka.todorova@mail.ru)

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### 1. INTRODUCTION

Crimea is located within the 44<sup>0</sup> 23' (Cape Sarich) and 46<sup>0</sup> 15' (Perekopsky earth trench) north latitude and 32<sup>0</sup> 30' (Cape Karamrun) and 36<sup>0</sup> 40' (Cape lantern) east longitude (fig.1). The area of the Crimean peninsula is 26,0 thousand km<sup>2</sup>, the maximum distance from north to south - 205 km, from west to east - 325 km. A narrow eight-kilometer strip of land in the



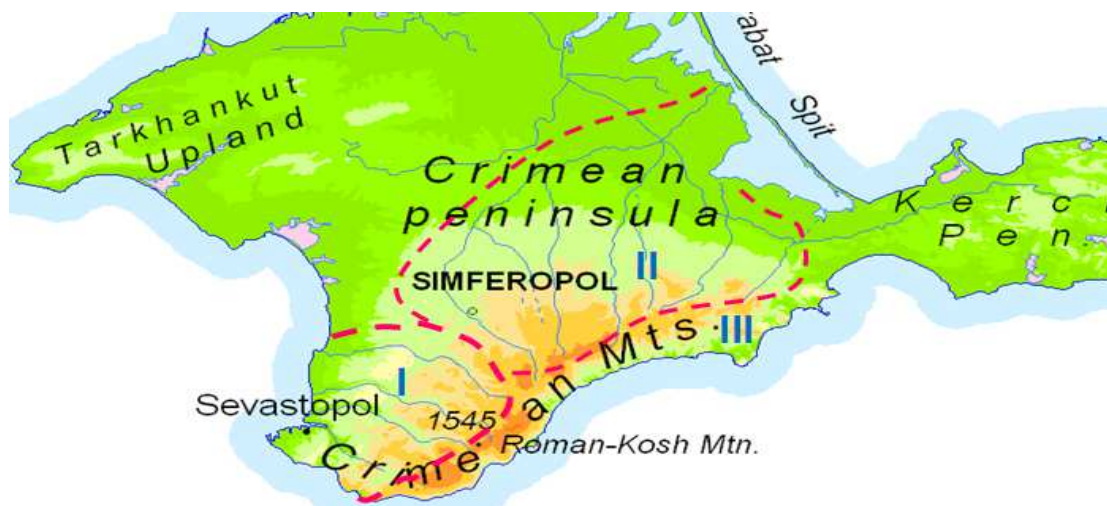
north (Perekop isthmus) connects Crimea with the mainland, and 4-5 kilometers - the width of the Kerch Strait in the east (Strait length of about 41 km) - separate it from the Taman Peninsula. The total length of the borders of the Crimea exceeds 2,500 km (including extreme tortuosity of the northeast coastline). Due to its characteristics of the Crimean peninsula is divided into three parts: the steppe Crimea, Kerch Peninsula and Mountain Crimea.



**Fig.1.** Location map of Crimea

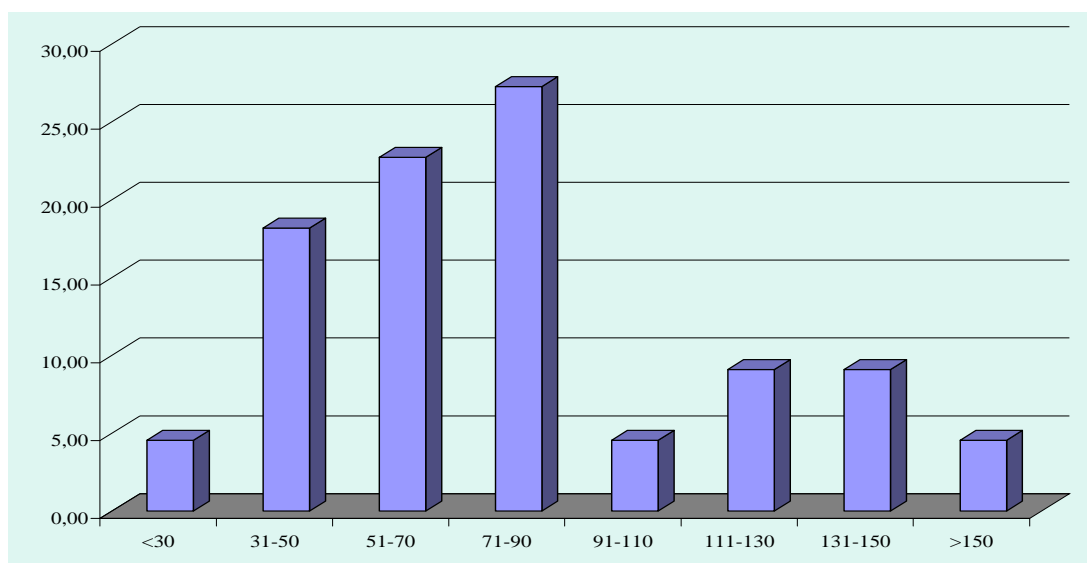
The rivers of Mountain Crimea are characterized by frequent rain floods. Formation of rain floods is associated with rainfall torrential character that covers a relatively small catchments area. After the falling large amount of precipitation the river is turning in turbulent flows with discharge of water, many times greater than the average value that can lead to disastrous consequences. In Crimea, 80-85% of the annual precipitation falls as rain. On the mountain of the Crimean rivers cause flooding rains that accompanied the demolition of eroded rocks. Rainstorms, at the same time never cover the entire Crimea. They typically fall in any one area. Most often heavy rains and downpours occur within one day. Flooding warm season on the rivers are not observed at the same time. For example, in the western part of the rivers of

the northern slope of the Crimean Mountains, the maximum discharges of the warm period observed most frequently in April-July. By the rivers of the southern coast of Crimea - from April to August, and the eastern part of the rivers of the northern slope - in the spring (fig.2).



**Fig.2.** Map hydrological zoning of Crimea (I – the rivers western part of the northern slope of the Crimean Mountains; II – the rivers eastern slope of the Crimean Mountains; III - the rivers of the Southern coast of the Crimea)

The analysis showed (fig.3) that on the territory in question is most frequently observed maximal quantity rainfall is 71-90 mm (27.3%), for the formation of flood warm season is characteristic rainfall is in the range 31-70 mm (total probability - is 40, 9%).



**Fig.3.** The distribution of rainfall floods warm period, abscissa - precipitation layer, mm; the vertical axis - the percentage of the total

Last official publication, that provides design characteristics of maximum runoff on this territory dates back to 1973.

Given the fact that over the past 40 years there has been climate change, both regional and global scale, it interesting to investigate possible trends in the maximum flow of the rivers and determine its modern characteristics.

## 2. METHODS

To assess the statistical homogeneity of the initial information used three criteria: F-test (Fisher criterion), Student's t-test and Wilcoxon criterion. The assessment of cyclical fluctuations maximal runoff is performed using the differences-integral curves, and statistical processing using the method of moments and maximum likelihood. The estimation of the significance of correlations realized using Pearson correlation coefficient, as well as using the Spearman rank tests and Kendall [1].

For calculation of maximum runoff of rain flood for ungauged rivers used the so-called «operator» model for maximum runoff formation that was described in detail in [2,3]. The following calculation equation is the basic:

$$q_m = q'_m \Psi\left(\frac{t_p}{T_0}\right) \varepsilon_F, \quad (1)$$

Where  $\Psi(t_p / T_0)$ - transformation functions;  $\varepsilon_F$  - coefficient of channel and flood plain storage;  $q'_m$  - is the maximum modulus of slope influx, equal to:

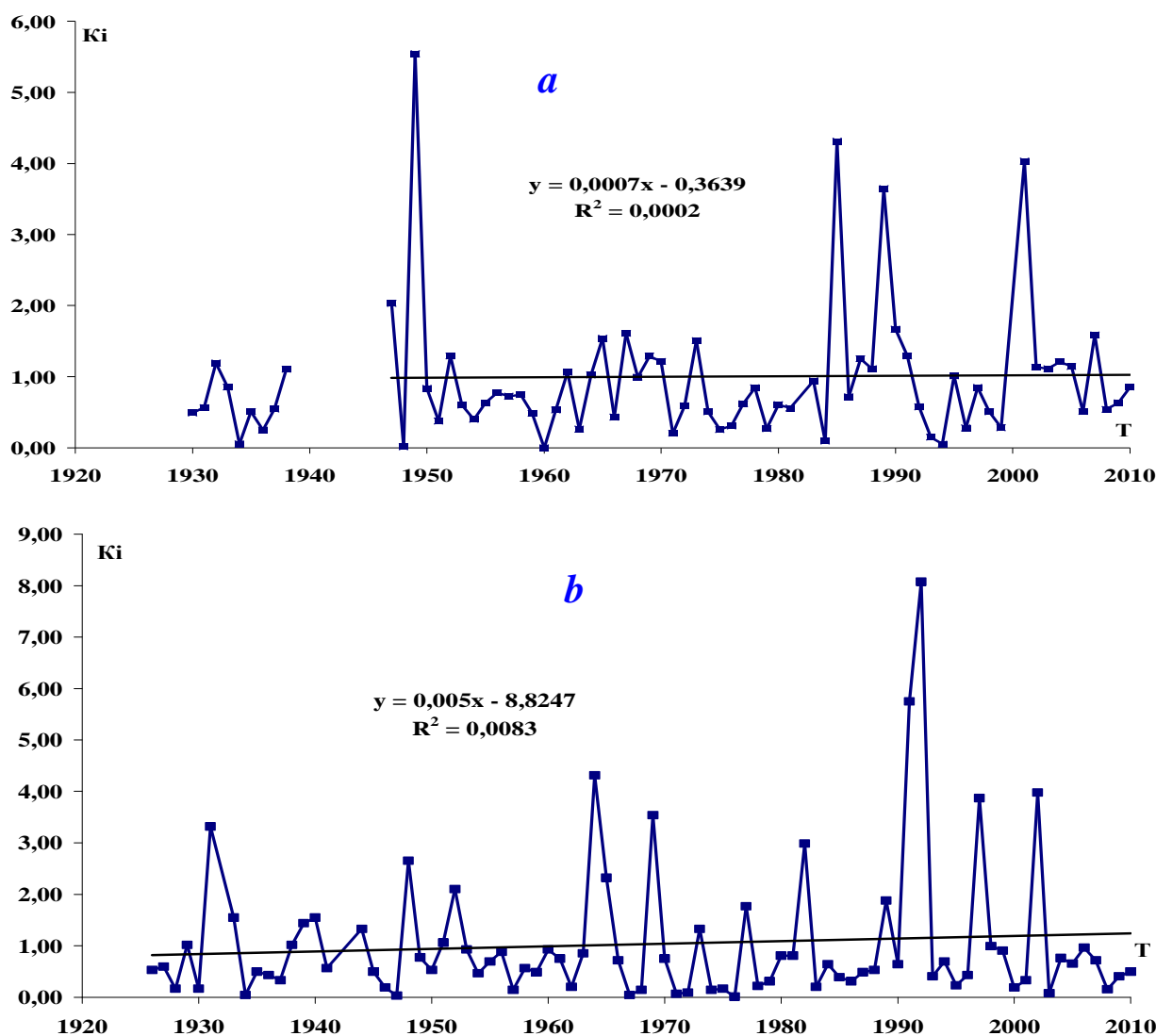
$$q'_m = \frac{n+1}{n} \frac{1}{T_0} Y_m, \quad (2)$$

Where  $(n+1)n$  – irregularity coefficient for slope influx;  $T_0$  - duration of slope influx;  $Y_m$  – layer of slope influx.

## 3. RESULTS OF INVESTIGATION

Analyzing the results of the estimation of homogeneity, it should be noted that the characteristics of rain floods of the Crimean rivers in most cases are homogeneous in time. Checking the homogeneity was conducted on the ranks with duration more than 40 years of

observations using F-test (Fisher criterion), Student's t-test and Wilcoxon criterion. The maximum discharges of rain floods are homogeneous in 21 cases out of 23, based on three criteria it means that 91.3% of ranks are homogeneous. A similar situation observed for the series of layers of rain floods - they are homogeneous in 20 cases out of 22, based on three criteria (91%). In general, the information's on the maximal runoff of rain floods should be considered homogeneous (Table 1, 2). To analyses the possible temporal trends in the ranks of the high flow floods warm period were built chronological charts, which can identify patterns and trends of long-term fluctuations layers of runoff and water discharges. Analyzing the graphs, it can be noted that trend is virtually absent on the studied rivers of the Crimean Mountains (correlation coefficient  $r = 0.014$  to  $0.091$ , that well can see on the fig.4).



**Fig.4.** The temporal trends of maximum runoff rain flood (a - Chernaya river, b - Su-Indol river)

**Table 1.** The results of the estimation of homogeneity maximum water discharge to river Mountain Crimea

River- streamflow station	n, years	The level of significance, %	F-test (Fisher criterion)		Conclusion about homogeneity	Student's t-test		Conclusion about homogeneity	Wilcoxon criterion	Summary conclusion about homogeneity
			F	F <sub>cr</sub>		t	t <sub>cr</sub>			
1	2	3	4	5	6	7	8	9	10	11
Alma - Krymderzhzapovidnyk	41	1%	1,33	3,92	yes	0,18	2,74	yes	yes	yes
		5%		2,74	yes		2,04	yes		
Kacha- Bashtanovka	43	1%	3,32	3,68	yes	0,08	2,72	yes	yes	yes
		5%		2,62	no		2,03	yes		
Kacha-Komsomolske	57	1%	6,97	2,81	no	0,71	2,67	yes	yes	yes
		5%		2,17	no		2,01	yes		
Belbek- Kuybysheve	77	1%	1,18	2,51	yes	0,34	2,65	yes	yes	yes
		5%		2,,00	yes		1,997	yes		
Belbek- Fruktove	71	1%	5,06	2,58	no	1,47	2,66	yes	yes	yes
		5%		2,04	no		1,99	yes		
Biyuk Uzen-Bash- Schaslyve	51	1%	2,02	2,94	yes	0,6	2,68	yes	yes	yes
		5%		2,25	yes		2,01	yes		



1	2	3	4	5	6	7	8	9	10	11
Chernaya-Rodnykivske	72	1%	1,12	2,54	yes	0,13	2,65	yes	yes	yes
		5%		2,02	yes		1,998	yes	yes	yes
Kokkozka-Aromat	40	1%	4,99	4,16	no	1,14	2,75	yes	yes	yes
		5%		2,86	no		2,04	yes	yes	yes
Uchan Su-Chehove	62	1%	2,36	2,61	yes	1,14	2,66	yes	yes	yes
		5%		2,06	no		2	yes	yes	yes
Derekoyka-Yalta	77	1%	1,73	2,51	yes	0,46	2,65	yes	yes	yes
		5%		2	yes		1,997	yes	yes	yes
Demerdzhi-Alushta	59	1%	1,91	2,77	yes	0,43	2,67	yes	yes	yes
		5%		2,16	yes		2,006	yes	yes	yes
Ulu-Uzen- Sonyachnohirske	61	1%	1,24	2,74	yes	0,65	2,67	yes	yes	yes
		5%		2,14	yes		2,004	yes	yes	yes
Taraktash-Sudak	60	1%	6,65	2,81	no	2,04	2,67	yes	yes	yes
		5%		2,17	no		2,007	no	yes	no
Kyzyltashskyy-Schebetovka	54	1%	22,68	2,9	no	0,64	2,68	yes	yes	yes
		5%		2,23	no		2,01	yes	yes	yes

1	2	3	4	5	6	7	8	9	10	11
Su-Indol-Topolivka	80	1%	10,19	2,41	no	2,1	2,65	yes	yes	yes
		5%		1,94	no		1,99	no	yes	no
Salhyr-Pionerske	56	1%	1,48	2,87	yes	0,54	2,68	yes	yes	yes
		5%		2,21	yes		2,009	yes	yes	yes
Anhara-Perevalne	58	1%	2,61	2,81	yes	0,8	2,67	yes	yes	yes
		5%		2,17	no		2,007	yes	yes	yes
Burulcha-Mezhyhir'ya	65	1%	1,95	2,71	yes	1,18	2,66	yes	yes	yes
		5%		2,12	yes		2,003	yes	yes	yes
Biyuk-Karasu-Bilohirsk	44	1%	2,47	3,68	yes	0,61	2,72	yes	yes	yes
		5%		2,62	yes		2,03	yes	yes	yes
Kuchuk-Karasu-Bahate	59	1%	18,001	2,81	no	2,04	2,67	yes	yes	yes
		5%		2,17	no		2,007	no	yes	no
Kuchuk Uzen-Bash - Mnohorichchya	46	1%	1,24	3,45	yes	0,31	2,71	yes	yes	yes
		5%		2,51	yes		2,02	yes	yes	yes
Kuchuk tributary Uzen Bash	46	1%	1,98	3,45	yes	1,21	2,71	yes	yes	yes
		5%		2,51	yes		2,02	yes	yes	yes
Uskut-s.Pryvitne	41	1%	2,49	3,92	yes	1,99	2,74	yes	yes	yes
		5%		2,74	yes		2,04	yes	no	yes



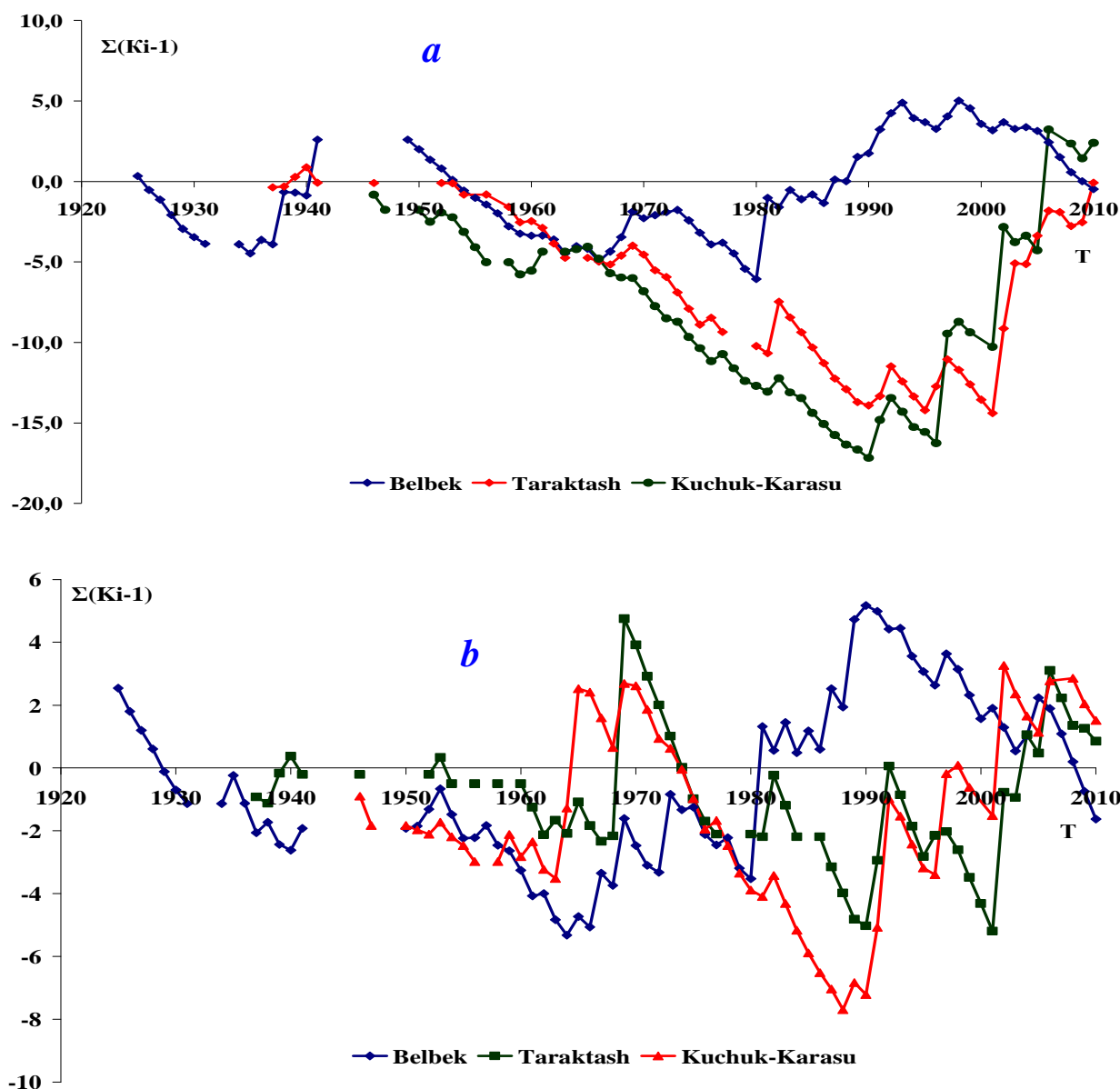
**Table 2.** The results of the estimation of homogeneity layers for maximum runoff rivers of Mountain Crimea

River- streamflow station	n, years	The level of significance, %	F-test (Fisher criterion)		Conclusion about homogeneity	Student's t-test		Conclusion about homogeneity	Wilcoxon criterion	Summary conclusion about homogeneity
			F	F <sub>cr</sub>		t	t <sub>cr</sub>			
1	2	3	4	5	6	7	8	9	10	11
Alma - Krymderzhzapovidnyk	41	1%	1,6	3,92	yes	1,56	2,74	yes	yes	yes
		5%		2,74	yes		2,04	yes		yes
Kacha- Bashtanovka	43	1%	1,86	3,68	yes	0,15	2,72	yes	yes	yes
		5%		2,62	yes		2,03	yes		yes
Kacha-Komsomolske	60	1%	2,16	2,81	yes	0,41	2,67	yes	yes	yes
		5%		2,17	yes		2,01	yes		yes
Belbek- Kuybysheve	76	1%	1,69	2,51	yes	0,31	2,65	yes	yes	yes
		5%		2,001	yes		1,997	yes		yes
Belbek- Fruktove	70	1%	1,043	2,61	yes	1,17	2,66	yes	yes	yes
		5%		2,06	yes		2	yes		yes
Biyuk Uzen-Bash -Schaslyve	51	1%	3,77	2,94	no	1,2	2,68	yes	yes	yes
		5%		2,25	no		2	yes		yes

1	2	3	4	5	6	7	8	9	10	11
Chernaya-Rodnykivske	74	1%	1,42	2,58	yes	0,39	2,66	yes	yes	yes
		5%		2,04	yes		1,99	yes	yes	yes
Kokkozka-Aromat	40	1%	1,55	4,16	yes	0,36	2,75	yes	yes	yes
		5%		2,86	yes		2,04	yes	yes	yes
Uchan Su-Cehove	62	1%	1,71	4,73	yes	0,68	6,59	yes	yes	yes
		5%		3,21	yes		4,92	yes	yes	yes
Derekoyka- Yalta	79	1%	2,89	2,48	no	2,38	2,65	yes	yes	yes
		5%		1,98	no		1,996	no	no	no
Demerdzhi-Alushta	60	1%	3,6	2,81	no	0,71	2,67	yes	yes	yes
		5%		2,17	no		2,01	yes	yes	yes
Ulu-Uzen- Sonyachnohirske	62	1%	1,15	2,77	yes	0,61	2,67	yes	yes	yes
		5%		2,16	yes		2,01	yes	yes	yes
Taraktash-Sudak	59	1%	1,14	2,81	yes	0,24	2,67	yes	yes	yes
		5%		2,17	yes		2,01	yes	yes	yes
Kyzyltashskyy-Schebetovka	53	1%	17,15	2,9	no	1,39	2,68	yes	yes	yes
		5%		2,23	no		2,01	yes	yes	yes

1	2	3	4	5	6	7	8	9	10	11
Su-Indol-Topolivka	82	1%	2,72	2,45	no	0,35	2,65	yes	yes	yes
		5%		1,96	no		1,995	yes	yes	yes
Salhyr-Pionerske	56	1%	2,65	2,81	yes	2,65	2,67	yes	yes	yes
		5%		2,17	no		2,007	no	no	no
Anhara-Perevalne	59	1%	1,61	2,81	yes	0,16	2,67	yes	yes	yes
		5%		2,17	yes		2,01	yes	yes	yes
Burulcha-Mezhyhir'ya	65	1%	1,057	2,71	yes	0,49	2,67	yes	yes	yes
		5%		2,12	yes		2,003	yes	yes	yes
Biyuk-Karasu- Bilohirsk	43	1%	1,69	3,68	yes	0,54	2,72	yes	yes	yes
		5%		2,62	yes		2,03	yes	yes	yes
Kuchuk-Karasu-Bahate	60	1%	1,92	2,81	yes	0,8	2,67	yes	yes	yes
		5%		2,17	yes		2,01	yes	yes	yes
Kuchuk Uzen-Bash - Mnohorichchya	46	1%	1,5	3,45	yes	0,8	2,71	yes	yes	yes
		5%		2,51	yes		2,02	yes	yes	yes
Uskut-Pryvitne	40	1%	1,56	4,16	yes	1,01	2,75	yes	yes	yes
		5%		2,86	yes		2,04	yes	no	yes

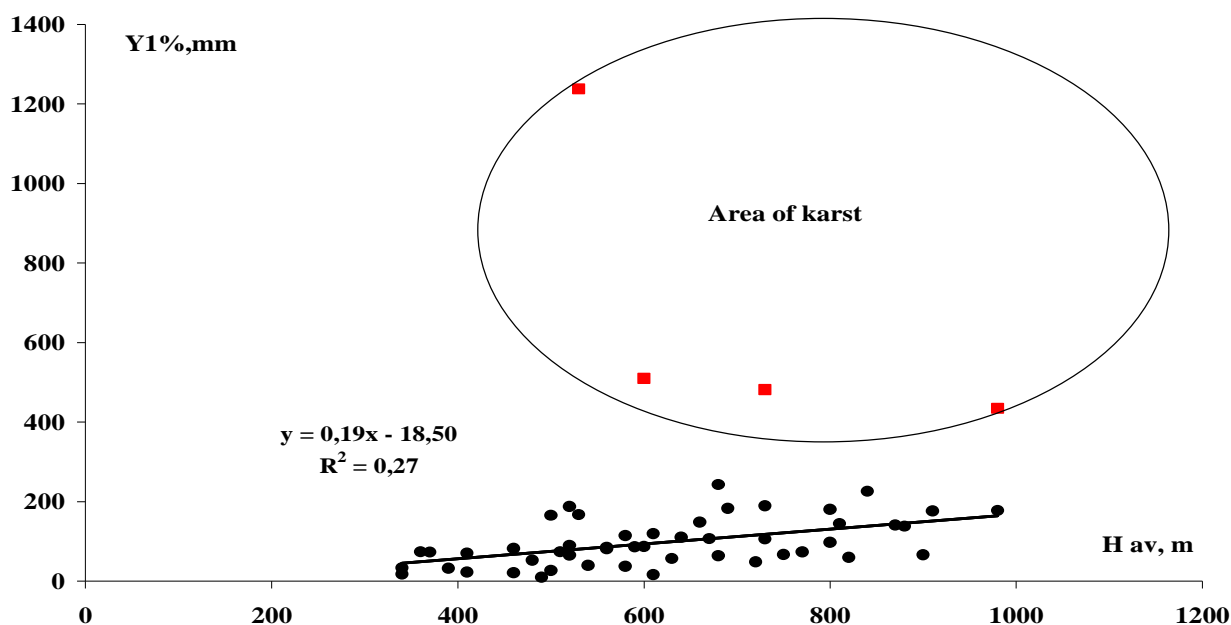
To characterize the cycling fluctuation of discharges and maximum layers are constructed the difference integral curves for the rivers of the Crimean Mountains (fig.5). In general we can say that the phase of water content of maximum runoff Crimean rivers are practically identical, and discrepancies in the flow can be explained by different exposure slopes with respect to moisture air masses and characteristics of the underlying surface (eg, the presence of karst)[4].



**Fig.5.** Difference-integral curves of maximum water discharges (a) and layers runoff (b) of rain floods for the rivers of the Crimean Mountains:  
 1 - r. Belbek (the north-western slope of the Crimean Mountains);  
 2 - r. Taraktash (southern coast of Crimea);  
 3 - r. Kuchuk-Karasu (north-eastern slope of the Crimean Mountains)

One of the principal tasks under development of methods for maximum runoff is generalization the runoff layers. Proceeding to spatial generalization of the layers of runoff in mountain districts, it is necessary, in the first instance, to consider that the characteristics of runoff in the mountains, as distinct from those of the flat lands, are subject not to geographical zonality but altitudinal zonation.

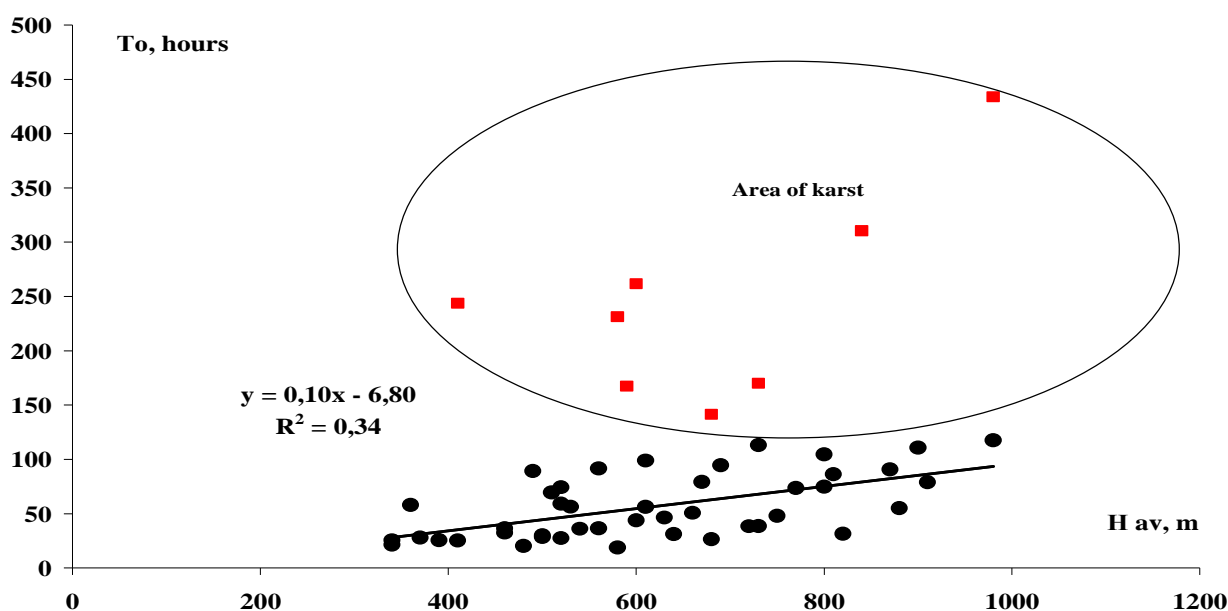
For the rivers in the mountain of the Crimea this dependence is clearly traced - the layer increases with an increase in the altitude of a locality, on the other hand, in the studied area there is another factor which substantially influences the runoff distribution in a territory - it is the karst. Such dependence for the  $Y_{1\%}$  (layers of runoff) is shown in fig. 6



**Fig.6.** Dependence  $Y_{1\%}$  on the average altitude of water catchment area of the rivers of the Crimean Mountains

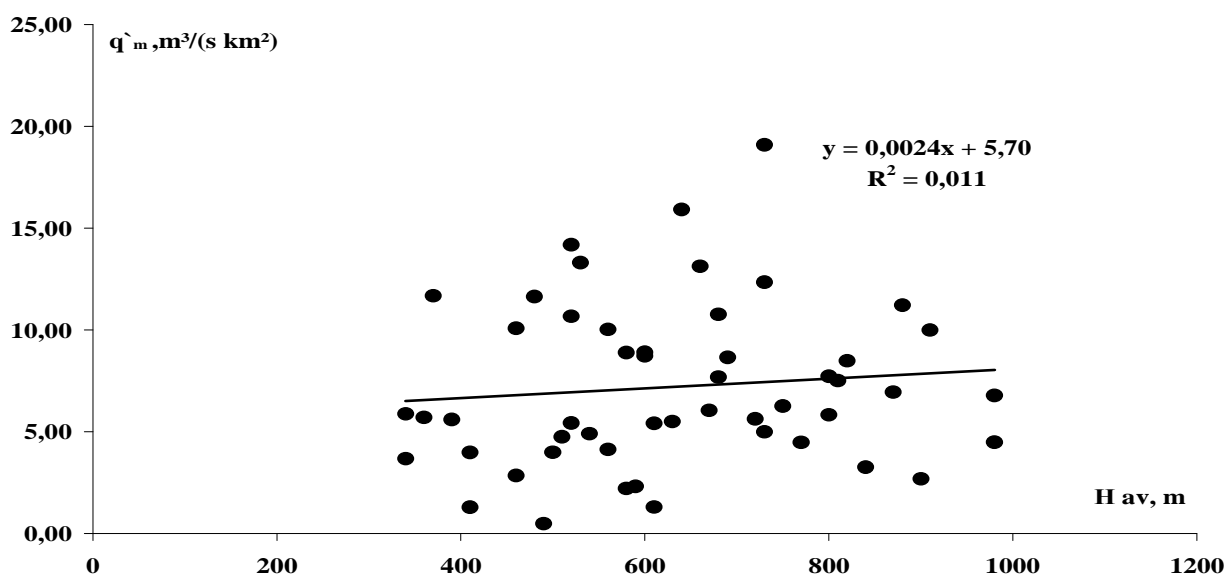
Similar dependence is observed for another characteristic of hillslope runoff - its duration. As is shown in fig. 7, we have distinct pattern of an increase in the studied parameter with the altitude in cases for most of the rivers, but as in case with the runoff layers there is another factor that has strong influence - this is the karst [5].

As for irregularity coefficient for slope influx, its average for rivers of investigated territory is 16.



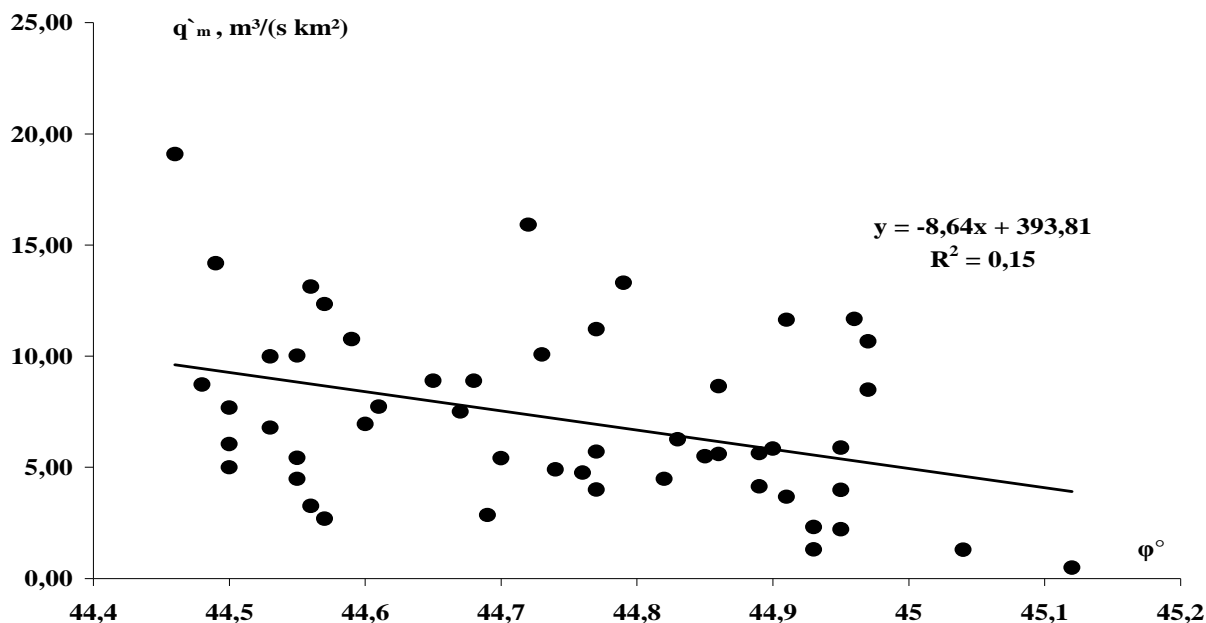
**Fig.7.** Dependence of the duration of slope influx on the average altitude of a water catchment area of the rivers in the Crimean Mountains

Taking into account that the constituents of the maximum modulus of hillslope influx depend on the altitude and vary in one direction, we had suggested that the integrated characteristic of slope influx (the maximum modulus of slope influx), that calculated by formula (2), will depend from altitude too. But, as well illustrates fig. 8,  $q'_m$  is almost independent of this factor.



**Fig.8.** Dependence of the maximum modulus of hillslope inflow on a locality altitude

Since the dependence the  $q'_m$  from the altitude is not observed, it was studied the effect on this characteristic the latitude. The dependence of the maximum modulus of hillslope influx from latitude is presented in fig. 9.



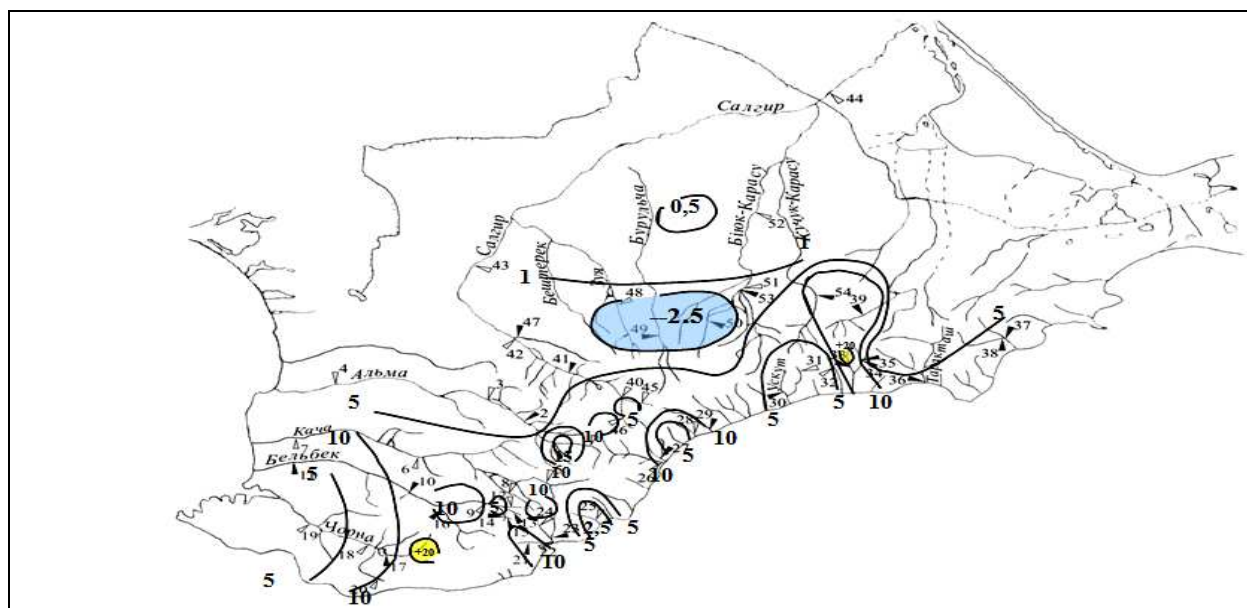
**Fig.9.** Dependence of the maximum modulus of hillslope influx on latitude

The significance of the obtained dependence was tested on three criteria - by Pearson's correlation coefficient and two ranking nonparametric criteria Spearman and Kendall (tabl.3) In this case the dependence is quite clear, with a significant correlation coefficient, which is the basis for mapping the maximum modulus of slope influx (fig 10).

**Table 3.** Estimate of the significance of correlation between the maximum modulus of hillslope Cremlia rivers and latitude its watersheds by 5% level of significance

<b>Pearson correlation</b>	Conclusion about the significance criterion	<b>Spearman rank tests</b>	Conclusion about the significance criterion	<b>Kendall rank tests</b>	Conclusion about the significance criterion
-0,39	<b>significant</b>	-0,302	<b>significant</b>	-0,219	<b>significant</b>

In general, the maximum modulus of slope influx vary in direction from the northeast from  $0.5 \text{ m}^3/\text{s km}^2$  to  $15 \text{ m}^3/\text{s km}^2$ , from the south-west, on the contrary first a decrease of  $20 \text{ m}^3/\text{s km}^2$  to  $2.5 \text{ m}^3/\text{s km}^2$ , and then there is a tendency to increase up to  $20 \text{ m}^3/\text{s km}^2$ . The general rule are violated the karst areas in which the observed value of runoff above (area of discharge) and considerably lower (karst area feeding) than zoning values.



● Area of karst discharge ( $20 \text{ m}^3/\text{s km}^2$ ) ● Area of karst supply ( $2,5 \text{ m}^3/\text{s km}^2$ )

**Fig.10.** Schematic map of the maximum modulus of slope influx

#### 4. CONCLUSION

- ✓ Analysis of cyclicity of maximum runoff rain floods in the Crimea showed no significant trends, and the presence of several complete cycles of the oscillation of water content.
- ✓ These results allow the use of statistical methods for the valuation characteristics of the maximal runoff.
- ✓ As calculating are proposing the technique by professor Gopchenko based on the theory of bed isochron.
- ✓ Testing calculations for the proposed method show good agreement with its precision baseline information that allows us to recommend it to practical application.



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