Journal of Climate Change, Vol. 2, No. 2 (2016), pp. 83–87.
DOI 10.3233/JCC-160019

Estimation of Statistical Characteristics for Storm Precipitation with Long-term Data to Assess Climate Change

V. Ilinich*, E. Akulova, V. Belchihina and K. Ponomarchuk

Department of Meteorology, Hydrology and Water Flow Regulation, Institute of Environmental Engineering of Russian State Agrarian University, Moscow str. Timiryazevskaya 49 - 127550, Russia
✉ vv_ilintch@mail.ru

Received February 22, 2016; revised and accepted May 14, 2016

Abstract: The article is dedicated to researches of the climatic changes and of the methods of their estimations, in particular with respect to quantity of the storm rain precipitations. The researches have been made on the base of data observation of meteorological station which has long-time series of the observed daily precipitations during 120 years. Special statistical methods were used for estimation of their changes in respect to the different concrete probabilities. All numerical results have shown an existence of the increasing trend of the daily dangerous extreme precipitations during time.

Keywords: Climatic changes, Storm rain, Random distributions, Statistical characteristics.

Introduction

In recent past, several researchers have concluded about an increase of quantity of storm rains, in particular, about increase of the quantile values of the random distributions in respect to 5% (Groisman et al., 2005; Dore, 2005; Endalew, 2007; Sen Roy, 2009). Such increase is connected with climate warming and increase of the water vapor content in troposphere. However, the stated position may be taken just by scientific hypothesis which requires confirmation in respect to concrete regions because the conclusions may be drawn just on the basis of long-time series of observations. Consequently the main aim of the research was a test of the scientific hypothesis in respect to changes of probabilistic characteristics of precipitation which were calculated on the basis of concrete observed data. According to the main aim the next problems were decided:

- to form the time series of the observed precipitations, which provide accurate calculation of their statistical characteristics;
- to research and clarify different statistical characteristics of the observed precipitations;
- to estimate quintile values of the random distributions in respect to 5% and 10% at last years and relative to the observed time series of 19 and 20 centuries; and
- to estimate the frequency of the maximum daily precipitation which are more of concrete storm values in different time series of observations.

The object of research was taken city Simferopol located on east shore of the Black Sea, where a meteorological station has long-time series data about daily precipitation beginning from year 1886.

*Corresponding Author

Methods and Materials

Full row of the checked data observations consisted of 120 years of daily precipitation. An approach to the forming of the statistical time series of the extreme precipitation has own peculiarities, since several catastrophic values may appear during calendar year, but for the another year we may not observe any significant rain. It is necessary to notice—we do not have the proved mathematical approaches for estimation of probabilistic characteristics—extreme rains because their formation is complex process. Accordingly we can't pick up a fairly objective method for forming a statistical number and appropriate distribution law of random variables at the present stage. We need a new hypothesis and a much longer period of observation of weather phenomena. Usually short rain with precipitation layer less than 15 mm can't lead to dangerous flood. So, two statistical ranks have been formed relative to daily storm precipitation:

1. Time series 1 involves values of the maximum daily precipitation for each year (total 120 members, among which there are values less than 15 mm, that was obtained arbitrarily).
2. Time series 2 involves all values which exceed the daily rainfall with layer of 15 mm (total 369 values).

At first the time series 1 was represented by chronological graph of Figure 1 where we can see a trend to increase.

The calculations of main statistical characteristics were performed along the statistical ranks: for all 120 years of observations; for the first 80 years; in last 40 years. Method of moments (Kristoforov, 1988; Dmowska et al., 2011; Wilks, 1999) was used to obtain the following basic statistical characteristics: average of maximum daily precipitation (X_o), standard deviation (σ), coefficients of variation (Cv) and skewness (Cs). Quintiles of maximum daily precipitation ($X_{p=0,1\%}$) relative to 0,001 probability of accidence were defined according to special Gamma-distribution of random values. Their numerical values are presented in Table 1.

Results of Table 1 allow conclusion about increasing of maximum daily precipitations during last 40 years (average X_o and quintile $X_{p=0,1\%}$ are most values).

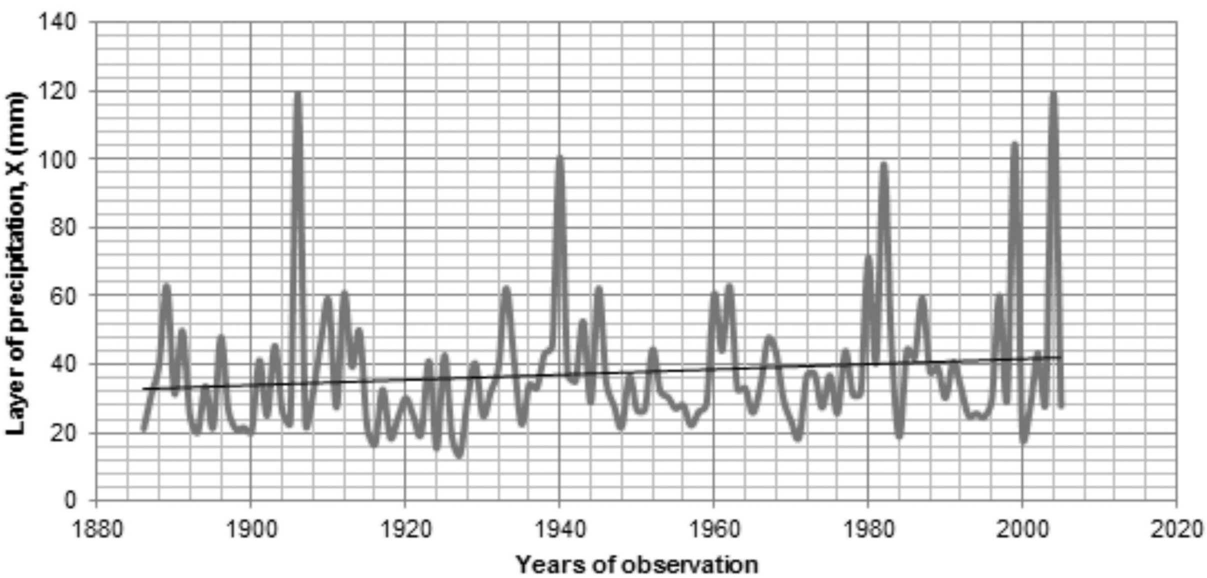

Figure 1: Chronological graph of maximum daily precipitation for the years of time series 1.

Table 1: Main statistical characteristics of the time series 1

Years of observations	*The main statistical characteristics of the maximum daily precipitation during the survey period*					
	X_o, *mm*	σ	*Cv*	*Cs*	*Cs/Cv*	$X_{p=0,1\%}$, *mm*
1886-1965 (80 years)	36.06	17.3	0.48	2.12	4.41	143.5
1966-2005 (40 years)	40.9	22.3	0.54	2.09	3.87	184.8
1886-2005 (120 years)	37.7	19.2	0.51	2.25	4.11	159.9

Estimation of Asymmetry for Statistical Ranks of Observations

We have to notice relative results of Table 1 where usually the first two statistical parameters can be defined enough exactly by different methods already for the 30 years of observation however the third statistical parameter has significant statistical errors [Ilinich, 2010; 2014; Kristoforov, 1988; Sen Roy, 2009) for 100-150 years of observation which depend on the variation coefficient (Cv).

There is classical method of moments among others for evaluation of Cs that uses next formula:

$$Cs = N \times \sum(X_i - X_o)^3/(N - 1)(N - 2)\ \sigma^3 \qquad (1)$$

where X_i – observed values of precipitation during every year (i); X_o – average value; n – amount observed for the time series; σ – middle square deviation; N – total amount of members in the statistical row (i = 1 … N).

The formula (1) involves differences between observed values and their average raised in third level therefore relative error of skewness (Cs) is very significant. Therefore there is offer for assessment of the asymmetry that depend on other statistical characteristics to frame some distributions of random values. The researches (Ilinich, 2010; 2014) have shown that there are dependences between Cs and parameters a, B, c:

$$a = 1/n\sum (1/K_i); \qquad (2)$$

$$B = 1/n\sum \exp K_i \qquad (3)$$

$$c = 1/n\sum 1/\exp(K_i - 1) \qquad (4)$$

where modular coefficient $K_i = X_i/X_o$.

The dependences have crisp graphics but they can't be represented by formulas. The parameters (a, B and c) have the small statistic errors comparative with Cs.

All computations in above mentioned statistical parameters are presented in Table 2 with respect to different quantity of members of the observed time series on the meteorological station.

We can conclude from Table 2 that there are significant fluctuations of the several parameters (essentially Cs) even with long-term observations. Their percentage deviations from conditional "true" values of parameters for asymmetry are presented in Figure 2. The conditional "true" values were calculated for 120 summer series.

Figure 2 allows the conclusion that parameter "c" is stabilized already after 30 years of observations and its deviations are not more than 2%. So skewness (Cs) was defined on the base of dependence between Cs and parameter "c" in the frame special Gamma-distribution of random values. The statistical parameters were taken equal to average X_o = Cs = 4Cv and Cv = 0.51. These parameters were checked based on the analysis of the differences between the quintiles of the analytical probabilistic curve and their empirical values which were obtained with the help of Weibull formula (Ilinich, 2014; Kristoforov, 1988).

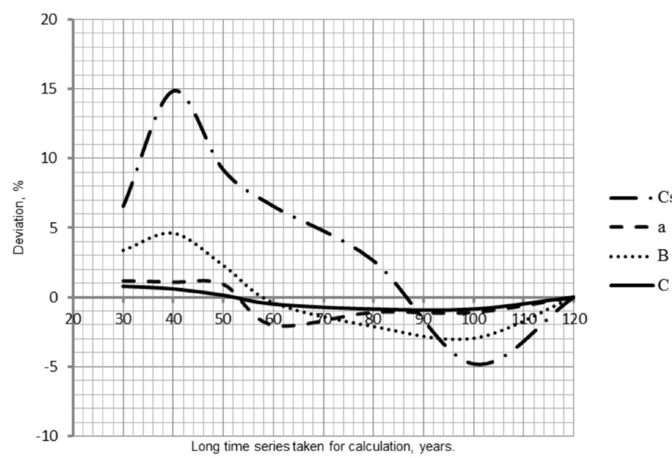

Figure 2: The percentages deviations from the "true" values of asymmetry parameters.

Table 2: Values of statistical parameters of maximum daily precipitation

N years	*Average*	*Cv*	*Cs*	*a*	*B*	*c*
30	37.14	0.548	2.44	1.206	3.432	1.108
40	34.51	0.54	2.63	1.205	3.473	1.106
50	34.1	0.522	2.5	1.203	3.396	1.101
60	38.46	0.51	2.44	1.168	3.307	1.094
100	36.38	0.48	2.18	1.179	3.222	1.09
120	37.38	0.513	2.29	1.192	3.32	1.0995

Estimation Quintiles of the Random Distribution

A sufficiently long series of observed maximum daily precipitation has allowed to estimate quintiles of the random distributions in respect to 3%, 5% and 10% enough exactly for different periods on the base of empirical probabilistic curves of maximum daily precipitation (Figures 3, 4 and 5). The quintile values were defined with the help of Weibull formula (Ilinich, 2014; Kristoforov, 1988) and of the corresponding empirical probabilistic curves (Figures 3-5).

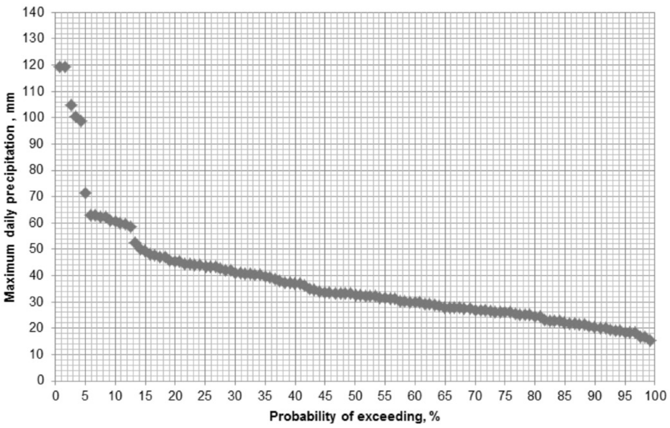

Figure 3: Probabilistic curve of exceedance annual maximum daily precipitation for the period of observation 1886-2006 years.

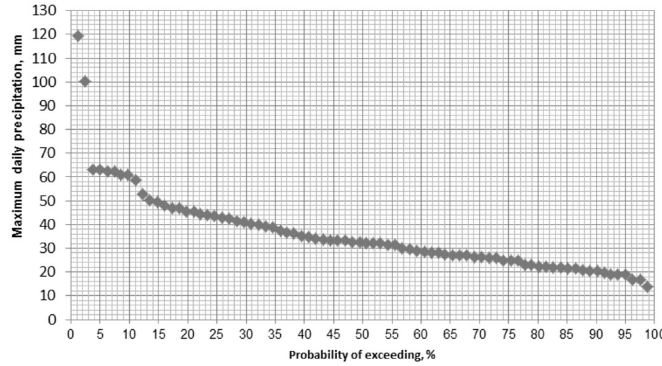

Figure 4: Probabilistic curve of exceedance annual maximum daily precipitation for the period of observation 1886-1965 years.

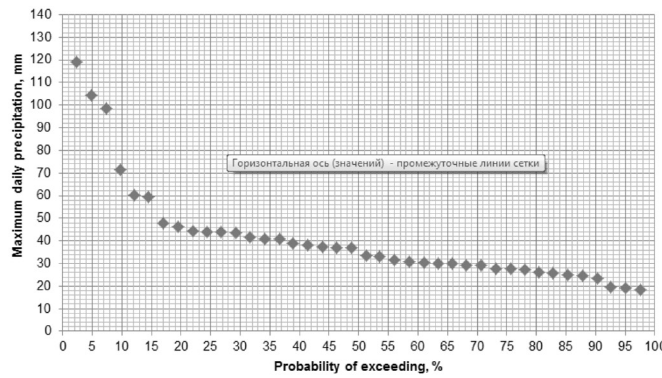

Figure 5: Probabilistic curve of exceedance annual maximum daily precipitation for the period of observation 1966-2006 years.

We can see (Table 3) the most significant values have place in last period. That proves an existence of trend to the rising of dangerous storm precipitation.

Main statistical characteristics were defined of the time series of observations 2 too. Results are represented in Table 4.

If we compare values of Table 4 and Table 1, we can conclude next: variability has decreased, but skewness has increased, so it is obviously that quintiles should have significant differences relative to quintiles of the time series 1.

Table 3: Quintile values in respect to different probability (P%) of exceedance of daily precipitation

Years of observations	*Quintile values of exceedance of daily precipitation*		
	P = 3%	*P = 5%*	*P = 10%*
1886-2006	102	71	61
1886-1965	86	63	61
1966-2005	114	105	73

Table 4: Main statistical characteristics of the statistical rows of daily precipitation generated from time series 2

Layer of daily precipitation, mm	*Amount of members in statistical row*	*Statistical characteristics*			
		X_o	*Cv*	*Cs*	*Cs/Cv*
X >15 mm	369	30.3	0.43	3.5	8.1

Estimation of Changes for Frequency Storm Precipitation

Time series 2 (369 values) involves very dangerous cases of exceeding of daily precipitation which are equal to 40 mm and 60 mm. Quantity of such cases is represented in Figures 6 and 7 in respect to equal duration of time series but different periods. Analysis of graphs in Figures 6 and 7 show the increasing of cases of dangerous precipitations in chronological development.

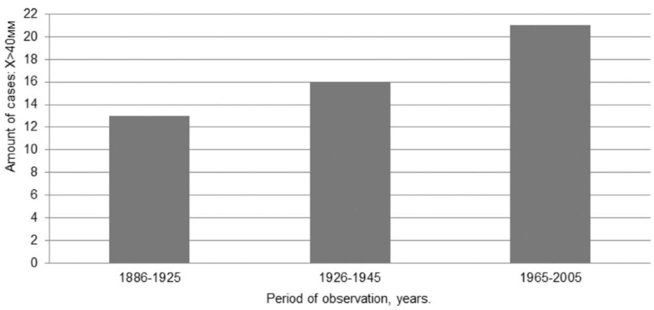

Figure 6: Amount of cases of exceedance of daily precipitation 40 mm (X > 40 mm).

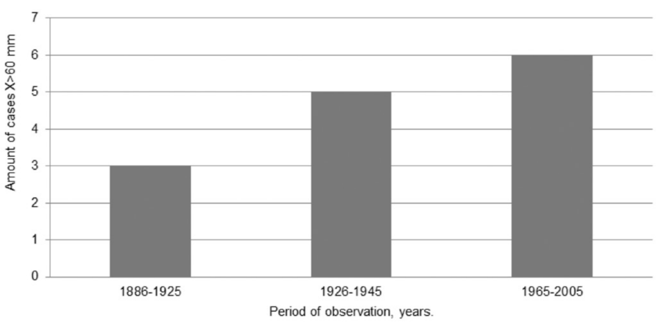

Figure 7: Amount of cases of exceedance of daily precipitation 60 mm (X > 60 mm).

Summary

1. All research aspects prove that there is clean chronological trend of the increasing of the daily dangerous extreme precipitations several times during the year.
2. Question about the correct mathematical assessment of the daily dangerous extreme precipitations in respect to their probabilities remains open.
3. It is justified to use some non-standard functions proposed in (Endalew, 2007; Ilinich, 2010) for evaluation of the asymmetry of series of meteorological and hydrological observations.
4. In the presence of long meteorological observations (over 100 years), there is no need to build analytical curves of probability (P = 3%, P = 5%, P = 10%) depending on the parameters Cv and Cs in the cases of presence of long meteorological observations (over 100 years). Such curves are required for assessment of dangerous phenomena for estimated quantiles of the distribution (P = 0.1%, P = 0.5%, P = 1%).

References

Dmowska, R., Hartman, D. and Rossby, H.T. (Eds) 2011. Statistical methods in the Atmospheric Sciences. Inter. Geoph. Series, Oxford, OX51GB, UK.Vol. 1.

Dore, M.H.I., 2005. Climate change and changes in global precipitation patterns: What do we know. *Environment International*, **31(8):** 1167–1181.

Endalew, G.J., 2007. Changes in the frequency and intensity of extremes over Northeast Africa. KNMI, WR 2007-02.

Groisman, P.Y., Knight, R.W., Easterling, T.R., Hegerl, G.C. and Razuvaev, V.N., 2005. Trends in intense precipitation in the climate record. *J. Climate*, **18:** 1326–1350.

Ilinich, V.V., 2014. Evaluation of asymmetry for ranks of extreme hydrological values. Proceedings of Conference: “21 century: Fundamental science and technology III”, Vol. 3, North Charleston, SC, USA 29406:10-13.

Ilinich, V.V., 2010. Assessment of skew in the frames of three-parametric gamma distribution. *J. Prirodoobustroystvo*, **5:** 71–75 (In Russian).

Kristoforov, A.V., 1988. Theory of probability and mathematical statistics. Moscow University (In Russian).

Sen Roy, S., 2009. A spatial analysis of extreme hourly precipitation patterns in India. *International Journal of Climatology*, **29(3):** 345–355.

Wilks, D.S., 1999. Inter annual variability and extreme-value characteristics of several stochastic daily precipitation models. *Agricultural and Forest Meteorology*, **93(3):** 153–169.