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MONITORING AND DYNAMICS OF CLIMATIC EXTREMES

Abstract: The long-term dynamics of climatic extremes is considered one of the necessary elements for monitoring the climatic system. A number of observations are made by the authors who explain the problem of tracing the evolution of thea modern climate. The dynamics of extreme precipitation is the most changeable element of the climatic system. The shifting from predictions based on estimations of the changes in climate to more general probability measures is justified as the most adequate means for obtaining reliable scientific information about climatic fluctuations.

Key words: climate, probability, description, monitoring.

1. Introduction

The changeability of the climate is an integral part of a general weather image in any region. Therefore, it is rather important from the point of view of explaining changes in climate to define in what system of „coordinates" we are. We see, for example, that the widely discussed issue of the increase in temperature in the world is a phenomenon that has happened before. It was noticeable in the instrumental period and, if we take longer time perspective, in the scale of climate variability the increase in temperature was even larger (Velichko 1991). Since the main problem of understanding and predicting the climate both for the general public and the professional and scientific community is linked with strong changeability of climatic parameters, it is necessary to answer this question: To what time scale do observable changes in climate correspond? That is to say, it is necessary to determine the time scale of the climate including its modern changes to organise an appropriate monitoring. Methods of submission of climatic data are needed to find a measure of this variability.

Therefore, it is not sufficient to limit the research of changes in climate only to long-term research, if the climatic characteristics are somewhat dynamic in shorter periods and are dissimilar in different regions. It becomes very important to understand the nature of climate complexity. Thus, concepts connected to temporal and spatial characteristics of climate (droughts, floods, heat and cold waves) are the long-term phenomena of weather. The mode of this extreme climatic phenomena is more important usually than the average conditions or even their average distribution.

2. Database and Methods

For evaluating changes in climate, comprehensive information about the dynamics in particular meteorological elements can be obtained by using the law of distribution P. In this case, an evaluation of the consequences of observable and expected variations in climate can be reduced to a comparison of the distributions of analysed parameters corresponding to a specific condition of climatic system $P_1(X_1)$; $P_2(X_2)$; $P_n(X_n)$. Additionally, one can suppose that a deformation of distribution caused by a displacement of norms of climatic parameters does not change the law of distribution itself. One may also suppose that the changes can be exhibited much better by studying the most changeable elements of climatic system (for example, atmospheric precipitation) at an extremely small level of geographical generalisation. Therefore, it is quite important to evaluate timeframes for the possibility of a recurring extreme climatic condition, in particular for unique climatic phenomena taking place in the history of a region's climate. Obviously, if the scale of an extreme climatic phenomenon will be comparable to a period of observation, it can be considered as an extremely rare climatic phenomenon. By its extremely small probability, the phenomenon can be used as an important prognostic indicator of a violation of climate's stability (in this case statistical stability).

One can make the comparison, for example, by calculating a dimensionless parameter:

$$\eta_i = a_{1i} / a_{2i} \quad i=1,2... n \qquad (1)$$

where: *a* is the average value of dispersion and other statistics, and recurrence of specific significance of climatic parameters calculated for compared conditions of climatic system.

The given approach was applied to the territory of the Republic of Moldova. Observational data on atmospheric precipitation for the period 1891-1996 were used. Within the limits of the selected period, the study focused on two stages of evolution of the regional climate:

1. Natural (1891-1940);
2. Natural - technological (1946-1996).

This implies that in the second case the climate tests for the Republic of Moldova are under „anthropogenic pressures", which can have an effect on the characteristics of the climatic system. It is obvious that such subdivision has a conditional character.

3. Results

In Table 1 the significance of the relative parameters η is shown, illustrating changes of statistical characteristics (average values η_x, average square deviations $\eta\delta$, recurrence of various of precipitation η). The relative changes (η_i) in the probability of different statistical significance in the total precipitation are calculated by threshold significance observed in modern climatic conditions (II period) once for 5, 10 and 20 years. As shown in Table 1, the changes in average values of the total precipitation were made within the limits of 10-40%. The maximum changes of average significance are specific for winters. The increase in average values of total precipitation does not necessarily lead to greater variations in total precipitation. For example, during the summer and the whole year, the increase averages for total precipitation fell within10%, whereas characteristics of variability ($\eta\delta$) remained constant.

Comparing the significance of parameter η by pairs, it is not difficult to notice that practically in all cases the change of probability exceeds the expected changes in averages. It is important to note that the given effect is more distinguished the less often it reoccurs. Within the limits of compared stages of the evolution of the regional climatic system, the maximum change of average values did not exceed 40%, whereas the probability of incidents of significance for total precipitation were observed once in five years. In some seasons of a year, they changed 5 times. The recurrence of high significance for total precipitation took place 10 times. The probability for incidences of low significance in total precipitation was once in 5, 10 and 20 years. The probabilities (20%, 10% and 5%) for the year and in winter were reduced almost twice. The recurrence of low significance of the totals in the summer and autumn

Tab. 1. Changes in the characteristics of distribution for seasonal totals of precipitation by converting from natural to natural-technological stage in the development of regional climatic system in the Republic of Moldova.

Parameter	Winter	Spring	Summer	Autumn	Annual
η_x	1.4	1.0	1.1	1.0	1.1
η_σ	1.3	1.1	1.0	0.9	1.0
Recurrence of low significance					
η_5	0.50	1.0	0.8	0.8	0.6
η_{10}	0.45	1.0	0.6	0.6	0.5
η_{20}	0.49	1.0	0.6	0.5	0.5
Recurrence of high significance					
η_5	5.0	1.3	1.3	1.0	2.0
η_{10}	10.0	1.4	1.4	0.8	2.0
η_{20}	4.0	1.2	1.3	0.7	2.5

were changed, whereas in spring the probability of incidents of extremely low significance for total precipitation remained constant. Thus, the data listed in Table 1 testify to the significant changes of distribution characteristics for total precipitation over time. These changes, essential in the greater degree, are peculiar to extreme incidents of the given parameter rather than to average values of total precipitation. Considering the significant influence of extreme cases of precipitation (droughts, floods, hail storms, snow storms, etc.) on human activity, there is an obvious necessity for accurate and consistent recording of these temporary, but extreme variances in the mode of precipitation for regional management of climatic events. For comparison in Table 2 there are the data about the change of regional characteristics, important for distribution of atmospheric precipitation, which shows the scale of variation in the Republic of Moldova. According to this data, the variability in frequency of incidences for total precipitation in time compared with their regional change is much bigger.

However, it must be stated that, despite such essential changes in the probability of incidences of extreme precipitation during the evolution of the regional climate, the general number remains virtually constant (Daradur et al. 1996). These changes have a structural character and testify to the fact that modern climatic conditions in Republic of Moldova are more frequently characterised by incidences of extremely high precipitation. At the same time, the most recent years in the history of Moldova's regional climate were marked by a number of unique precipitation phenomena, earlier considered practically impossible to happen in the region. There are questions in this regard: If extreme climate phenomena occur and they exceed all previous instrumentally fixed significance, what is the probability of the reoccurrence of such phenomena? If the probability is not too small, then it is obvious that the potential for such extreme incidences within the framework of the given regional climate must be taken into account in economic and social planning. If the probability of their incidence is not too high, then they should not be considered. However, in this case, there is an

Tab. 2. Changes in the characteristics for distribution of seasonal and annual totals of precipitation in the Republic of Moldova.

Parameter	Winter	Spring	Summer	Autumn	Annual
η_x	1.05	1.3	1.2	1.1	1.2
η_σ	0.84	0.7	1.0	0.9	1.1
Recurrence of low significance					
η_5	0.66	0.40	0.50	0.66	0.40
η_{10}	0.50	0.25	0.33	0.51	0.28
η_{20}	0.50	0.16	0.10	0.50	0.25
Recurrence of high significance					
η_5	1.0	1.0	2.0	1.1	4.0
η_{10}	1.0	1.05	2.0	1.0	3.0
η_{20}	0.71	2.0	2.5	1.0	5.0

additional dilemma. When there is a problem with the stability and predictability of climate, assessments on the probability of any recurrence of such extreme climatic events based on existing experimental data are impossible.

The clearest expression of this problem were undoubtedly the meteorological conditions of 1994 in the Republic of Moldova, where the features of the hydrometeorological mode were unique. The first half of the year (January–July) and the first 10 days of August were characterised by the complete lack of precipitation. Additionally, in the last 10 days of August in many regions of Moldova the amount of precipitation exceeded all records known in the history of instrument observations. The total precipitation in August of this year was the greatest in the history of instrumental observations (1891-1996). In many regions of Moldova, the August precipitation amounted 150-200 mm compared to the average long-term value of 40-60 mm. For example, in Kishinev it exceeded 201 mm per month while the norm was 48 mm. Obviously, the sum of precipitation for August in 1994 deviated from the average within the limits of $201-48 = 153/35.2 \sim 4.3\delta$. The probability of such anomalies occurring in the conditions of the modern climate is practically equal to zero.

The evaluations conducted on distribution theory by Veibula corresponded most closely to the recorded incidence rainfall. This showed that the probability of such an amount of precipitation in August was 0.11%. The magnitude of the incident is negligible on the scale of the modern climate for it indicates that such heavy precipitation will occur on the average only once every 1000 years (Tab. 3).

Clearly, one can see that the mode of extreme precipitation really varies. By these results, estimations in the stability of climate are subject of doubt. It is impossible to judge the possibility of the occurrence of similar situations in climatic mode based on existing experimental data.

4. Conclusions

The most complete information on the dynamics of the climatic factors over time can be achieved with the application of the law of distribution, which reflects the full spectrum of variability for meteorological measures. Applying this law we

Tab. 3. Probability evaluations of incidences of extreme precipitation for August in Kishinev, Republic of Moldova.

Total Precipitation mm	Evaluation of Data			
	Instrumental		Calculated	
	%	# of times in N years	%	# of times in N years
≥200	0.95	105	0.11	934
≥150	1.90	52	1.11	89
≥100	6.66	15	8.27	12
≥10	5.71	16	8.01	12
≥3	0.95	105	1.94	51

find that in all cases the extreme changes in climate exceed those that are appropriate and expected for the average long-term parameters. In the conditions of modern climate, some extreme phenomena were observed which were considered practically impossible earlier in the region. These can be used for important prognostic indications violating the statistical stability of a regional climate.

Understanding that violations of the statistical stability of climatic system do occur, as expressed for example in the quantitative structure of extreme precipitation, is itself a rather important perspective from the position of climatic monitoring. Such phenomenon can be interpreted as an outcome of the growing anthropogenic influence on the Earth's atmosphere as a whole and such changes have the consequent impact on regional climatic systems. In particular, these departures from the norms have geographical consequences that can become a peak incident of extreme climatic phenomena. Therefore, the dynamics of climatic extremes can become one of the major elements used in tracing the evolution of a modern climate both on regional and global levels.

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