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ANALYSIS OF CLIMATE CHANGE FOR THE RECREATIONAL COMPLEX OF KISLOVODSK TOWN-RESORT (TRANSLATION OF THE ORIGINAL PUBLICATION INTO ENGLISH)

Research article

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Abstract

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Regional studies are the necessary fragments for constructing a general picture of climatic changes. Based on long-term observations (1961-2020) the following climatic parameters were analyzed in this work: average decade snow cover height, the atmosphere surface layer temperature and precipitation amount for Kislovodsk town-resort. According to the results of the analysis, the average annual temperature exceeded the climatic norm by 1.1 °C, while the amount of precipitation and the average decade snow cover exceeded the climatic norm by 0.8 mm and 0.3 cm, respectively. Seven extremes of average ten day snow cover height and one extremum of precipitation and average annual temperature were identified.

Keywords: average decade snow cover height, temperature regime, precipitation regime, regression analysis, change rate, climatic norm, extreme values.

АНАЛИЗ ИЗМЕНЕНИЯ КЛИМАТА ДЛЯ РЕКРЕАЦИОННОГО КОМПЛЕКСА ГОРОДА – КУРОРТА КИСЛОВОДСК (ПЕРЕВОД ОРИГИНАЛЬНОЙ ПУБЛИКАЦИИ НА АНГЛИЙСКИЙ ЯЗЫК)

Научная статья

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Аннотация

Перевод оригинальной публикации Кешева Л.А. Анализ изменения климата для рекреационного комплекса города – курорта Кисловодск // Л.А. Кешева, Р.Х. Калов // Международный научно-исследовательский журнал. — № 1 (127). — DOI: https://doi.org/10.23670/IRJ.2023.127.138.

Региональные исследования являются необходимыми фрагментами при построении общей картины климатических изменений. В данной работе на основе многолетних наблюдений (1961-2020гг.) проведен анализ изменения климатических характеристик: среднедекадной высоты снежного покрова, температуры в приземном слое атмосферы и суммы осадков для города-курорта Кисловодска. По результатам анализа получено превышение среднегодовой температуры на 1,1°С по сравнению с климатической нормой, сумма осадков и среднедекадная высота снежного покрова превысили климатическую норму на 0,8 мм и 0,3 см соответственно. Выявлены экстремальные значения: семь экстремумов среднедекадной высоты снежного покрова, и по одному экстремуму суммы осадков и среднегодовой температуры.

Ключевые слова: среднедекадная высота снежного покрова, температурный режим, режим осадков, регрессионный анализ, скорость изменения, климатическая норма, экстремальные значения.

Introduction

Currently, issues related to climate change in different regions, expanded the range of scientific interests, attracting the attention of not only specialists. Climate change has a direct effect on the population living needs. The reality of climate change is confirmed primarily by instrumental observation data. There are numerous papers devoted to the analysis and forecast of climate change in different regions of the world in the past, present and future time periods. Climate change detected through instrumental measurements is primarily observed in the increase in lower troposphere temperatures. This phenomenon was called "global warming" in the paper of Wallace Broecker [1]. In the [2], recommendations of the World Meteorological Organization (WMO), the beginning of global warming is considered 1976 bulletin of the eighth World

Meteorological Congress (April 30-May 25, 1979; Geneva, Switzerland)). Roshydromet annually reports on climate change in the territory of Russian Federation examine changes in temperature, precipitation, snow cover and other meteorological parameters since 1976 [3].

The contribution of natural and anthropogenic impacts to the unprecedented temperature growth in the lower troposphere is a scientific problem that has attracted and continues to attract great attention from researchers [4], [5], [6]. There are two extreme points of view on the main causes of rising temperatures:

1. Reasons of natural origin (astrophysical, leading to cyclical changes in temperature with a period from tens to hundreds of thousands years).
2. Anthropogenic causes (industrial activity, agricultural activity, deforestation).

In the work of Monin A.S., Sonechkin D.M. [7], in the context of past changes, climate fluctuations occurring at the present time were analyzed. Climate variations are considered as integrally non-stationary and locally appearing to be random, chaotic fluctuations in a nonlinear climate system under the influence of external forces of various natures changing over time.

In the works of Sorokhtin O.G. [8] and Kapitsa A.P. [9] talks about the opposite effect of the mutual impact of mean global temperature and carbon dioxide concentration. Namely: it is not the growth in carbon dioxide content in the atmosphere that affects the growth in air temperature. According to the authors [8], [9], on the contrary, rising temperatures lead to heating of the ocean surface and release of carbon dioxide into the atmosphere.

Kislovodsk (819 m a. s. l.) is a southern resort in the Caucasian Mineral'nyye Vody group. The resort city relief is varied and, together with medicinal mineral springs, is one of the main recreational resources of the territory; it is used to organize medicinal paths, walking, cycling routes. Sand and chalk highlands surrounding the city are very beautiful and form numerous terraces in which caves and grottoes are scattered [10]. Kislovodsk has been formed as a resort city, including due to its favorable climatic conditions. The climate study for the most southern resort in the Caucasian Mineral'nyye Vody group is necessary for the resort's recreational complex, for which over the past 60 years and since 1976 the change in meteorological parameters (temperature, precipitation, average 10-day snow depth) were studied.

Research methods and principles

Many Russian scientists' works are devoted to researching of climate change in the European territory of Russia (ETR). Kryshnyakova O. S. and Malinin V. N. in [11], [12] assess trends in precipitation and temperature fluctuations in the European territory of Russia. For our research, the North Caucasus Hydrometeorological Service kindly provided data on the average ten-day snow depth, temperature and precipitation for 1961-2020. The average ten-day snow depth was calculated as the average for the cold season (October-April) from 1960/61 to 2019/20 [13]. The *t*-test was used to determine statistically significant differences in the study variables. The average, maximum, minimum and extreme values, range, standard deviation, normality of distribution, skewness and kurtosis are determined. Regression analysis (SPSS 21.0 software package) made it possible to conduct a study aimed at identifying the main trends (*a*/10 years (yrs)), quartile analysis – at identifying extreme values of meteorological parameters [14].

Main results

Table 1 shows the main statistical characteristics of meteorological parameters for the study period 20 are given in table 1.

Table 1 - Statistical characteristics of meteorological parameters for 1961-2020, Kislovodsk

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No n/n	Statistics	Average ten-day snow depth, *h* (cm)	Temperature, *t* (°C)	Precipitation, *P* (mm)
1	Average (std. error), $x_{avg.}$	3.5 (0.3)	8.9 (0.1)	646.8 (14.7)
2	Standard deviation, *s*	2.6	1.1	113.7
3	Minimum	0.6 (1965/1966)	6.3 (1993)	442 (1994)
4	Maximum	12.5 (1991/1992)	11.1 (2018)	1006 (2002)
5	Range	11.9	4.8	564
6	Skewness	1.6	0.6	0.4
7	Kurtosis	2.3	-0.14	0.42
8	Normality of distribution, $P \geq 0.05$	0.34	0.73	0.36
9	Climate norm (1961-1990), *N*	3.2	7.8	646
10	t-тест, $x_{avg.} = N$ at *Sig.* ≥0,05	0.45	0.001	0.1
11	Extremes	3 extremes ≥ 7.8 cm	1 extreme ≥ 11.1°C	1 extreme ≥ 1006 mm

12	Trend slope, a_1 1961-2020	0.18 cm/10 yrs	0.32°C/10 yrs	-2.1 mm/10 yrs
13	Trend slope, a_2 1976-2020	-0.05 cm/10 yrs	0.67°C/10 yrs	-13.2 mm/10 yrs

The average value of the 10-day snow depth (1961-2020) was $h_{avg.}$=3.5 cm, minimum $h_{min.}$=0.6 cm occurred in the 1965/66 season, and the maximum $h_{max.}$ 12.5 cm – in 1991/92 (table 1). Long-term average snow depth $h_{avg.}$=3.5 cm slightly exceeded the climatic norm N_h=3.2 cm (1961-1990), but, according to the *t*-test (*Sig.*=0.45>0.05), remained within the boundaries of statistical equality. In the modern period (since 1976), the change in snow cover depth has a negative trend.

Since 1961, average annual temperatures have increased at a rate of 0.32°C/10 yrs (statistically significant contribution of the trend to the explained variance *D*=25.2%), since 1976 their growth has accelerated to 0.67°C/10 yrs (*D*=55.6%).

Long-term average $t_{avg.}$=8.9°C (1961-2020) statistically significantly exceeded the norm N_t=7.8°C (1961-1990). Long-term average precipitation $P_{avg.}$=646.8 mm (1961-2020) is statistically significantly equal to the norm N_p=646 mm (1961-1990). The Kolmogorov-Smirnov test showed that the annual amount of precipitation has a normal distribution curve (*Sig.*=0.358>0.05). The asymmetry coefficient is less than one and positive, that is, there is a slight excess of the number of years with values above average (Fig. 1).

The rate of change in annual precipitation showed a negative trend for 1961-2020 (a_1=-2.1 mm/10 yrs, *D*=0.1%) and in the period 1976-2020 (a_2=-13.2 mm/10 yrs, *D*=2.0%).

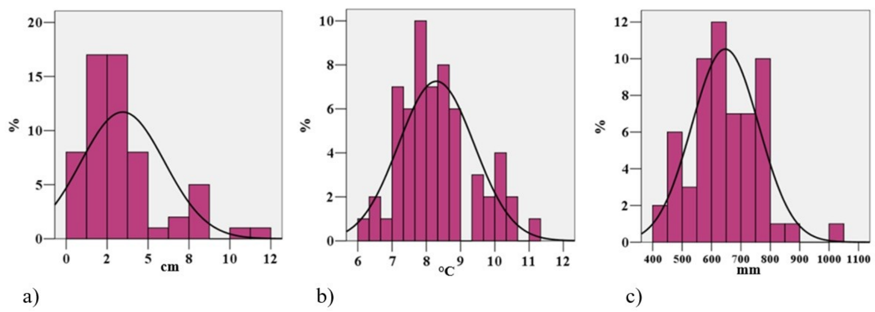

Figure 1 - Histogram of frequency distribution of climatic characteristics for 1961-2020:
a – average ten-day snow depth; *b* – temperature; *c* – amount of precipitation
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Extreme events are the consequence of climate change, the intensity of which is growing, and the frequency of their occurrence is also increasing. A climate extreme is the achievement of a meteorological or climate variable to a value that is above (below) some threshold [15], [16]. To detect the extremeness of the series, a ranked series was constructed, divided into quantiles (25%, 50%, 75%), after that the difference between the 75% and 25% quantiles was found. Values that exceed the difference of 75%-25% quantile by more than one and a half (three) are outliers (extrema) [14].

A graphical representation of the distribution of statistical and extreme characteristics of parameters (median, difference between 75%-25% quantiles, outliers, extremes) is available in Fig. 2.

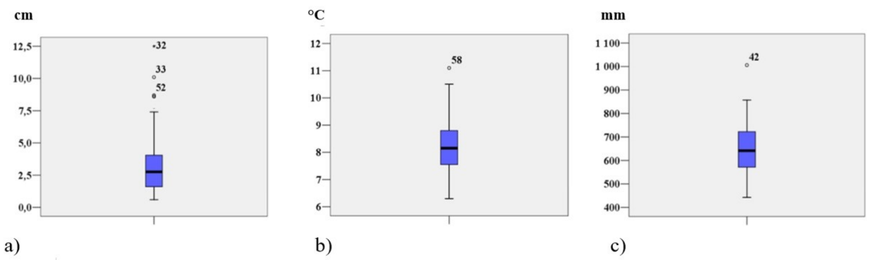

Figure 2 - Box plot with median and extremes for 1961-2020:
a – average ten-day snow depth; *b* – temperature; *c* – amount of precipitation
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From the quantile analysis, extreme values of the average ten-day snow cover height exceeding the threshold value *h*=7.8 cm were obtained in various years: h_{1992}=12.5 cm, h_{1993}=10.1 cm, h_{2012}=8.7 cm; one extreme value of the amount of precipitation and atmospheric surface air temperature: p_{2002}=1006 mm and t_{2018} =11.1°C.

Discussion

The purpose of this study is to identify patterns of changes in temperature, precipitation and snow depth, which must be taken into account for the successful functioning of the Caucasian Mineral'nyye Vody resort.

Climate change analysis is critical to minimizing the uncertainty and risks associated with significant increases in average annual temperatures coupled with modest decreases in annual precipitation and snow depth.

Our results demonstrated good agreement with the climate studies for various climatic zones of the Caucasus region obtained in works [17], [18], [19]. In work [17], carried out for a long period (1939-2017) in the foothill zone at the weather station (w/station) Vladikavkaz, it is shown that during the period of time under consideration, the dynamics of changes in the average annual temperature is negative. When selecting the period corresponding to ours (1961-2017), the indicators of all average seasonal and annual temperatures are positive and statistically significant. In the monograph [18], studies were carried out for various climatic zones of the region. In 1961-2018 there was a statistically significant increase in average annual temperatures: in the steppe zone by 0.28°C/10 yrs (*D*=25.68%), in the Caspian zone by 0.23°C/10 yrs (*D*=20.63%), in the foothill zone by 0.31°C/10 yrs (*D*=29.77%) and in the mountains by 0.24°C/10 yrs (*D*=23.05%) and in the Black Sea zone - the lowest rate of change in average annual temperature among statistically significant trends (0.16°C/10 yrs (*D*=11.83%)). The statistical significance of the increase in average annual temperature was not determined for the high-mountainous w/station Terskol (*b*=0.08°C/10 yrs, *D*=4%), except for summer temperatures (*b*=0.32°C/10 yrs, *D*=35.6%).

In [19], for the Caucasus region, according to the SMHI RCA4 climate model for two forecast periods (2021-2050 and 2071-2100), summer temperature forecasts are given. By the middle of the 21st century summer temperatures are expected to increase by an average of 1.5-2.0°C, and by the end of the 21st century – by 5-7°C.

Based on the results of our studies of climate change at the foothill w/station Kislovodsk, we can note an increase in the aridity of the territory: against the background of a significant acceleration in the growth of average annual temperature from 0.32°C/10 yrs (1961-2020) to 0.67°C/10 yrs (1976-2020) there is a decrease in precipitation. Thus, the favorable climatic conditions of the resort town may change for the worse.

Conclusion

This study examined long-term changes in temperature, precipitation, and snow depth using data from the Kislovodsk w/station (1961-2020). The results of this study showed that:

1. Since 1961, there has been a statistically significant increase (at a 5% level) in average annual temperatures – 0.32°C/10 yrs (*D*=25.2%), followed by an increase to 0.67°C/10 yrs (*D*=55.6%) since 1976. The long-term average annual temperature (1961-2020, $t_{avg.}$=8.9°C) exceeded the norm (1961-1990, *N*=7.8°C) by 1.1°C.

2. Over the study period, there was a statistically insignificant decrease in annual precipitation amounts (-2.1 mm/10 yrs, *D*=0.1%), which intensified since 1976 (-13.2 mm/10 yrs, *D*=2.0%).

3. The trend in the average 10-day snow depth changed its direction from positive in 1961-2020 (0.18 cm/10 yrs, *D*=1.4%) to negative in 1976-2020 (-0.05 cm/10 yrs, *D*=0.1%).

For successful management of the tourist and recreational complex, research on climate change is necessary. In this study, patterns of changes in temperature, precipitation and snow depth in the resort city of Kislovodsk were identified. An unfavorable combination of temperature and precipitation (temperature increase and precipitation decrease) in the future leads to an increase in the aridity of the study area, to a change in the structure of the landscapes of the study region and may have negative consequences for the tourist and recreational complex. Due to climate change, these types of analyzes are critical to minimizing the uncertainty and risks associated with resort operations.

Subsequent studies should be supplemented by factors that have a significant impact on the formation of temperature and precipitation regimes, namely: the main large-scale atmospheric circulations and anthropogenic impact.

Конфликт интересов

Не указан.

Рецензия

Все статьи проходят рецензирование. Но рецензент или автор статьи предпочли не публиковать рецензию к этой статье в открытом доступе. Рецензия может быть предоставлена компетентным органам по запросу.

Conflict of Interest

None declared.

Review

All articles are peer-reviewed. But the reviewer or the author of the article chose not to publish a review of this article in the public domain. The review can be provided to the competent authorities upon request.

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