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METEOROLOGICAL INDICATORS ANALYSIS OF THE TAMBUKAN LAKES AREA AS A BASIS FOR UNDERSTANDING THE FORMATION OF THEIR WATER-SALT BALANCE

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Due to the lack of a dedicated meteorological station in the Tambukan Lakes area, alternative approaches are required to obtain reliable climate data. This study addresses this gap by applying spatial interpolation techniques. The methodology is further complicated by the region's intricate topography, which significantly affects local temperature distribution. The article presents the results of reconstructing mean annual air temperatures in the Tambukan Lakes area due to the absence of local meteorological station (MS) data. Using geoinformation technologies based on the LLRA (Linear Lapse Rate Adjustment) method, observations from seven nearest MS (1955–2025), and the Shuttle Radar Topography Mission (SRTM) digital elevation model, the adjusted mean annual air temperatures for the lakes have been calculated. A comparison of the obtained values with the MS network data using Pearson's correlation coefficient has revealed the highest similarity with the station "Mineralnye Vody". Notably, the analysis demonstrated that despite the relatively short distance between the lakes and the "Mineralnye Vody" MS, systematic temperature differences persist due to elevation and local microclimatic conditions. This finding underscores the importance of elevation-based corrections rather than relying on raw station data. A detailed analysis has shown that the Tambukan Lakes area is systematically colder by 0.74℃, with a root mean square error of 0.8℃, which is considered acceptable. Annual precipitation totals have not been used as a primary criterion due to the complex relief of the Ciscaucasia Region, which influences air mass transport. The feasibility of using data from the "Mineralnye Vody" MS, for subsequent calculation of the water-salt balance of the lakes has been substantiated.

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***Keywords*:** Tambukan Lakes, meteorogical data reconstructing, annual air temperatures and annual precipitation totals, water-salt balance, station "Mineralnye Vody", LLRA, SRTM.

Introduction. Tambukan and Lake Maly Tambukan (Sukhoye), has been driven by the fact that these lakes are characterized by an unstable water regime, which can cause a deterioration in the quality of the therapeutic mud. The water level of the waterbody is prone to sharp and rapid fluctuations, the nature of which has

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been described in [1]. Some of the main factors and processes causing changes in the water level of the lakes include: the amount of atmospheric precipitation, its frequency and duration, air temperature, evaporation, and the characteristics of the transformation of atmospheric precipitation on the land surface and groundwater, which are necessary for calculating the inflow and outflow components of the water balance [1].

However, to quantify the impact of most of these factors, especially atmospheric precipitation and air temperature, long and continuous series of meteorological observations directly in the lake area have been required.

In their initial attempts to analyze the annual trends of climatic parameters in the area of Lake Bolshoy Tambukan, the authors have encountered some limitations, expressed in the absence of some data. The "Bolshoy Tambukan" station was likely closed in the mid-2010s, which has made direct measurement of climatic parameters in the immediate vicinity of the lake impossible, while data from the "Pyatigorsk" meteorological stations (MC) ceased to be published in official compilations in the late 1990s and has only become publicly available again in the last few years. In this regard, the authors have been forced to look for a MC that could be considered "representative" for further research series on Lake Bolshoy Tambukan.

To achieve this goal, data from the MC closest to the study site have been processed, and, based on these data, the reduced average annual air temperatures in the area of Lake Bolshoy Tambukan have been calculated using geoinformation methods. This has subsequently served as a comparative basis for selecting the MC with the most comparable climatic conditions.

Materials and Methods. The Tambukan Lakes are the main sources of centralized extraction of therapeutic mud, which belongs to siliceous sulfide peloids possessing unique healing properties. Due to this, they found wide distribution and application in various health resorts not only in the North Caucasus, but also in more than twenty other constituent entities of the Russian Federation (RF) [1–5]. They are located on the territory of two constituent entities of RF – Stavropol Krai and the Kabardino-Balkarian Republic (KBR), the border between which crosses the lake's water area from West to East and Southeast along the long axis and has a total length of about 2500 *m* [4, 5], and are separated by a narrow isthmus elongated in a submeridional direction. Lake Maly Tambukan is a drying lake and is filled with a 0.2–0.4 *m* water layer only in spring and early summer. The river net in the area of Lake Tambukan is developed quite well. All rivers flowing here belong to the Kuma River basin.

Lake Bolshoy Tambukan is located on the Kabardian Plain, 12 *km* from the City of Pyatigorsk [6, 7] and is a drainless waterbody that formed in the Late Neopleistocene-Holocene [8]. The relief of the area is a gently hilly plain with rolling watersheds. From the North and Northwest, the basin is framed by the Goryachevodsk Plateau (600–624 *m*), from the West by Mount Stolovaya (678–715 *m*) and the laccolith Zolotoy Kurgan (886 *m*), from the South by the Zolskoye Plateau (600–650 *m*), while to the East, the plain gently merges with the valley of the Etoka River [2], which, together with the Yutsa and Zolka Rivers, are the largest and closest flowing to the lakes. The Etoka River is located closest to the lake. In geological-structural terms, the study area is confined to the Eastern wing of the Kavminvodsky uplift, which is part of a large transverse Elbrus–Stavropol rise [8, 9]. The territory is composed of a thick sequence of Meso-Cenozoic terrigenous-carbonate deposits overlying dislocated Paleozoic rocks [8, 9].

Since 1972, an unprecedented rise in the water level of Lake Bolshoy Tambukan has been observed, accompanied by an expansion of its boundaries and an increase in the volume of the water mass. Thus, during the period 1972–2015, the surface area of the lake increased almost 1.5 times (from 1.58 km^2 in 1972 to 2.29 km^2 in 2015), and the volume of its water mass increased 16 times (from 714.7 thousand m^3 in 1972 to 11,379 thousand m^3 in 2015) [5, 10]. Due to the continuing rise in the lake's water level, two main threats arose: the desalination of the salt water, whose mineralization decreased to 25 g/dm^3, and the possibility of the erosion of its shores and the federal highway R217 (M29) "Kavkaz" by the lake's waters. The observed rise in water also affected the quality of the therapeutic sulfide muds, which are not only not inferior to the well-known peloids of the Dead Sea, but, by some balneological parameters, exceed them [1, 2]. Therefore, the issue of identifying the causes of the changes in the lake's water level became extremely relevant at the present time. However, despite numerous studies of the components of the lake's water balance, scientists did not manage to reach an unambiguous conclusion about the causes of the variations in the lake's level regime [2, 3]. In this regard, in this communication, we attempted to study the behavior patterns of several important hydrometeorological parameters, both at the local and regional scale.

One of the main inflow components of the water balance of Lake Tambukan is surface runoff entering the lake from the catchment area. The formation of surface runoff occurs under the influence of physical-geographical factors characteristic of the catchment area of the waterbody in question. To determine the main physical-geographical characteristics of the Lake Tambukan catchment area, such as the area and average elevation of the catchment, cartographic material at a scale of 1 : 25 000 was used. Fig. 1 shows a section of the map used to determine the physical-geographical characteristics, with the catchment boundaries marked. Cartographic analysis, which was verified in [10], made it possible to determine the average elevation of the Lake Bolshoy Tambukan catchment, which amounted to 607 *m* above sea level. The catchment area of Lake Bolshoy Tambukan, due to the constantly growing surface area of the lake, is not a constant value and changed from 18.06 km^2 to 17.34 km^2 during the period from 1972 to 2015.

Here is the translated text, following the rules of scientific English. The present perfect is used where appropriate (e.g., for stating established findings, results that remain relevant, or actions with present relevance), while past simple is used for specific past actions or observations. Other tenses (present simple, etc.) are used as needed.

The climate in the area of Lake Bolshoy Tambukan is characterized as moderately continental, typical of the foothill belt of the North Caucasus, with insufficient moisture, hot summers, and cold winters [11]. The long-term average annual air temperature has been recorded as 8.4°C, while the average monthly temperature in January drops to –4.8°C [2]. The number of sunny days per year reaches an average of 110, and the duration of the frost-free period is 173 days [2]. A characteristic feature of the microclimate of the lake area is a lower air temperature (especially in winter) compared to adjacent territories, which is associated with the orography and the presence of the water bodies themselves. The surface area of Lake Bolshoy Tambukan is about 1.9 *km*², with a maximum depth of up to 3.1 *m* [8]. The lake is probably fed at present mainly by rainwater and meltwater flowing down the mountain slopes.

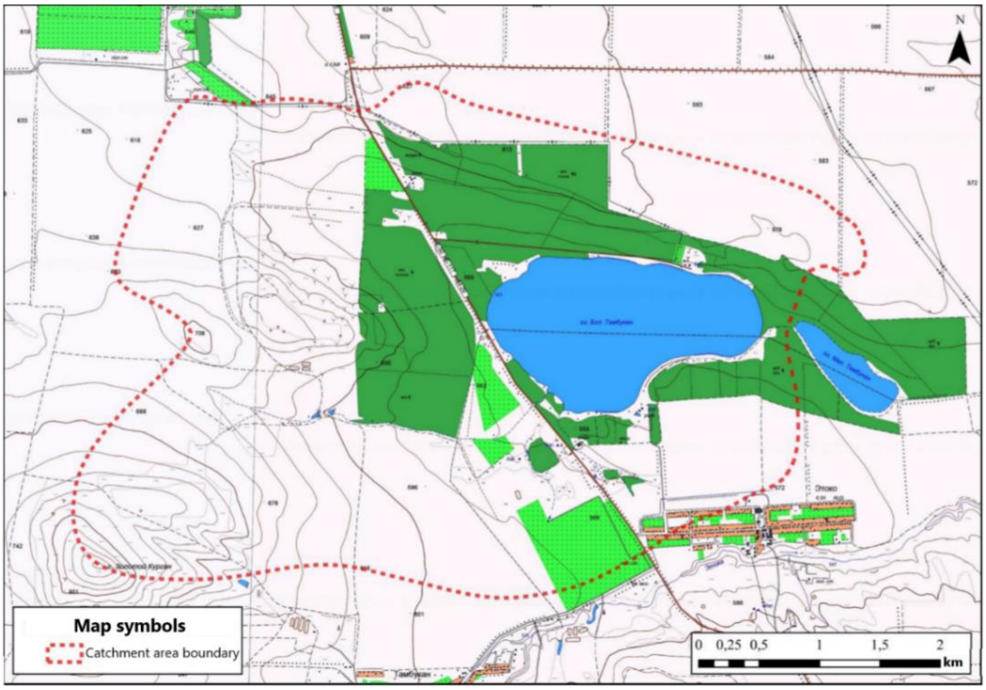

Fig. 1. Catchment area map of Lake Bolshoy Tambukan.

This study has used data from instrumental observations of MC in the Mineralnye Vody Region for the period from 1955 to 2025 [12]. Two main parameters have been subjected to analysis: average annual air temperature (°C) and annual total atmospheric precipitation (*mm)*. Time series processing, identification of main statistical characteristics, and assessment of the presence of trends have been carried out using descriptive statistics methods. To verify the strength and reliability of the identified relationships between climatic parameters, the Pearson correlation coefficient (r) was applied.

The assessment of the strength of the correlation was carried out in accordance with the Chaddock scale, which is widely accepted in geographical research, and the statistical significance of the obtained coefficients was tested by comparing them with tabulated critical values for the corresponding number of degrees of freedom (n–2) and an accepted significance level ($p < 0.05$). The application of this statistical apparatus has made it possible not only to quantitatively assess the relationships between elements of the climatic system but also to determine the reliability of the conclusions drawn.

Given the significant landscape and orographic diversity of the study area, the authors have analyzed 7 MC closest to the study lake, the grid of which covers the entire water area of Lake Bolshoy Tambukan (Fig. 2): “Mineralnye Vody”, “Georgievsk”, “Prokhladny”, “Nalchik”, “Tyrnyauz”, “Kislovodsk”, “Pyatigorsk”.

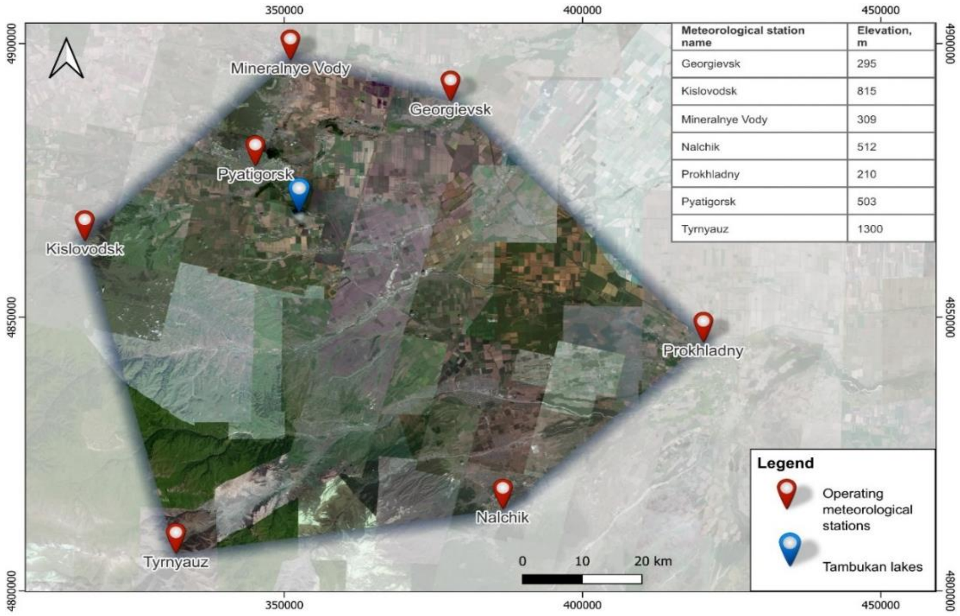

Fig. 2. The net of MC chosen by the authors for the research.

In the net under consideration, the station farthest from the lake is “Prokhladny”, located at a distance of approximately 72 *km*. This same station is situated lower than the others in terms of relief, at 210 *m* a.s.l. The closest station, “Pyatigorsk”, is about 11 *km* away. The highest elevation is observed at the Tyrnyauz station – 1300 *m* a.s.l. (Fig. 1).

Subsequently, the reduced average annual atmospheric air temperatures for each station have been obtained using the linear correction method for vertical temperature gradient, or Linear Lapse Rate Adjustment (LLRA), described in detail in [13]. This choice has been justified by the method's ability to account for the influence of relief on the temperature field, as well as its relative simplicity and computational efficiency when working with long-term data series. The SRTM v.3.0 (Shuttle Radar Topography Mission) digital elevation model with a spatial resolution of 1 arc-second, which corresponds to about 30 *m* on the ground, was used as the source of relief data. Temperature interpolation methods that account for digital elevation models have been widely used to construct climatic maps in areas with complex orography [14, 15].

The implementation of the method in the QGIS 3.40.0 geographic information environment included the following steps. Reduction of values to a reference elevation using the formula [13]:

$$T_{\mathrm{red.}} = T_{\mathrm{act.}} + \gamma(\Delta H),$$

where $T_{act.}$ is the average annual temperature at the MC, °C; γ is the vertical temperature gradient, 0.6°C/100 *m*; ΔH is the difference between the elevation of the MC and the elevation of Lake Bolshoy Tambukan, *m*.

Interpolation of the values reduced to the level of Lake Bolshoy Tambukan. In this study, the interpolation of annual air temperatures has been performed using spline interpolation (Multilevel B Spline Interpolation). This algorithm creates a smooth surface passing through the MC points and produces plausible isotherms, eliminating stepwise artifacts and the bullseye effect.

Reverse recalculation of the values to actual elevations using the formula:

$$T_{\mathrm{red.}} = T_{\mathrm{act.}} - \gamma(\Delta H).$$

Since the temperatures were reduced to the level of Lake Bolshoy Tambukan, and not to sea level as in [13], this step was only necessary to eliminate systematic bias. The difference between the back-calculated temperatures and the temperatures measured at the stations was 0°C.

Next, the reduced average annual atmospheric air temperatures and the data on average annual temperatures recorded at the stations have been subjected to correlation analysis in order to identify their relationship. Based on the calculated correlation coefficients, the most representative meteorological station has been selected. Trends of the calculated and actual average annual air temperatures have been constructed. The deviations between both parameters have been analyzed, and to assess the stability of the approach, the root mean square error (RMSE) has been calculated using the formula:

$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} \Delta T_i^2},$$

where ΔT_i is the difference between the reduced average annual temperature and the average annual temperature at the presumed "reference" station, °C.

Results and Discussion. Pearson correlation coefficients between the obtained temperature values and the actual data from seven MC that have operated during different periods within the Caucasian Mineral Waters Region are presented in Table.

Correlation coefficients between reduced average annual atmospheric air temperatures and average annual temperatures according to MC data

Meteorological station	Pearson correlation coefficient, *r*
Mineralnye Vody	0.966
Georgievsk	–0.005
Prokhladny	0.870
Nalchik	0.916
Pyatigorsk	0.381
Kislovodsk	0.921
Tyrnyauz	0.464

A very high positive statistically significant correlation with the reduced average annual temperatures has been observed at three MC: "Nalchik", "Kislovodsk", and "Mineralnye Vody". The correlation coefficients were 0.916, 0.921, and 0.966, respectively, $p < 0.05$. A high positive statistically significant correlation has also been recorded for the “Prokhladny” station, $r = 0.870$, $p < 0.05$. A moderate positive statistically significant correlation has been observed at two MC: “Pyatigorsk” and “Tyrnyauz”, $r = 0.381$ and 0.464, respectively, $p < 0.05$. Among those presented, no correlation with the reduced average annual atmospheric air temperatures has been observed at the “Georgievsk “MC. It is noteworthy that the strongest correlation with the reduced average annual atmospheric air temperatures at Lake Bolshoy Tambukan has been identified at the “Mineralnye Vody” MC, whereas the “Pyatigorsk” station is located significantly closer to the study site. The reasons for this include both gaps in the data from the “Pyatigorsk” MC from 1998 to 2013 and the location of the point at the foot of Mount Mashuk, which creates local microclimatic conditions not characteristic of the open area near Lake Bolshoy Tambukan. The “Mineralnye Vody” MC is located on a plain, in a foothill zone similar to that of the lake, without sharp orographic transitions, which has provided a more homogeneous temperature field. The performed correlation analysis has allowed the authors to conclude that the highest comparability exists between the calculated temperature data in the area of Lake Bolshoy Tambukan and the actual data from the “Mineralnye Vody” MC. Therefore, this station is subsequently used as a reference for constructing trends, calculating deviations, and verifying the obtained results.

Fig. 3 presents a graph of the reduced average annual temperatures at Lake Bolshoy Tambukan according to the LLRA method and the actual average annual temperatures according to the reference MC data for the observation period (1955–2025). Both trends demonstrate an increase in average annual atmospheric air temperatures. Furthermore, at both locations, the rate of temperature increase is 0.033°C per year, which is equivalent to 0.33°C per decade.

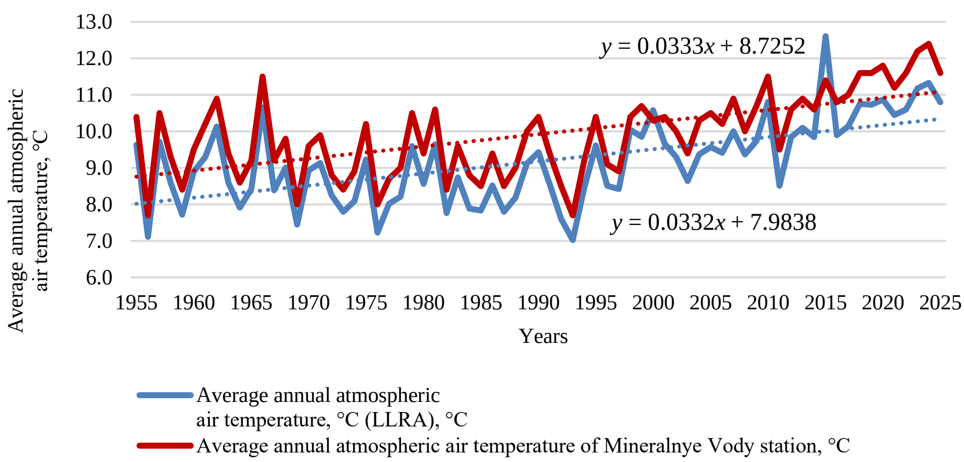

Fig. 3. Trends of reduced average annual temperatures at Lake Bolshoy Tambukan according to the LLRA method and actual average annual temperatures according to data from the “Mineralnye Vody” MC.

In general, the average annual air temperature in the area of Lake Bolshoy Tambukan over the 70-year period has been lower than at the “Mineralnye Vody” MC. This is particularly evident in Fig. 4.

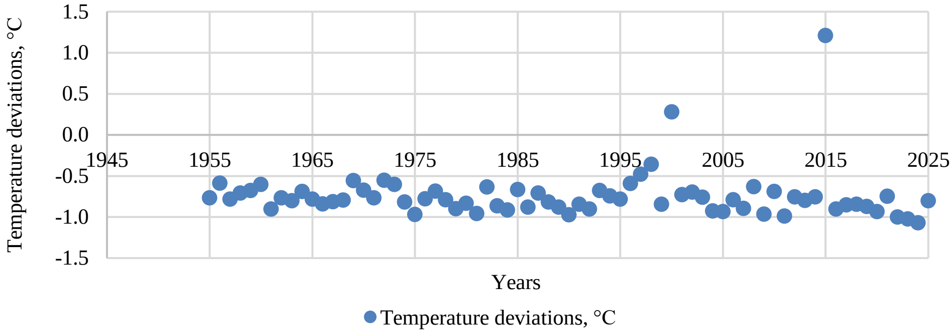

Fig. 4. Deviations of reduced average annual temperatures (LLRA) from actual average annual temperatures according to data from the "Mineralnye Vody" MC over 70 years.

On average, the data from the reference MC have exceeded the reduced data by 0.74°C. The range of deviations was 2.3°C. The maximum deviation was 1.2°C (2015). Although for the entire dataset, 2015 was one of the warmest years, in this case it rather indicates an outlier associated with overestimation of temperature by the interpolation method that uses a constant temperature gradient. In abnormally warm years, the actual gradient may be smaller, especially under stable anticyclonic weather. The exceedance in 2000 of 0.3°C is likely related to an interpolation shift due to missing data in a number of stations, which made the grid incomplete. Despite the artifacts present in some data, their number has been insignificant in the context of the entire study period.

The root mean square error for the average annual temperatures has been 0.8°C, which, together with the high correlation coefficient (0.966), in our view indicates the high accuracy of the applied LLRA method and the possibility of using data from the "Mineralnye Vody" MC for studying the water balance of Lake Bolshoy Tambukan.

Based on the data obtained by reconstructing the average annual temperatures over the territory covered by the MC net, maps have been constructed (Fig. 5) showing the temperature dynamics in 10-year intervals: for 1955, 1965, 1975, 1985, 1995, 2005, 2015, and 2025 (the average annual air temperatures (°C) in the lake area for these years were: 9.6, 8.4, 9.2, 7.8, 9.6, 9.6, 12.6, and 10.8, respectively). In general, the cartographic material reflects the situation observed in the temperature graphs (Fig. 3). Throughout the entire territory, as well as in the area of Lake Bolshoy Tambukan, an increase in average annual temperatures has been observed. This is particularly evident in the lowland areas, where since 1995 the temperature gradient has begun to equalize, reaching higher values compared to 1955–1985. Warming has also been observed in the highland parts near the "Tyrnyauz" station. For 1955 and 2005, negative values (down to –3°C) were obtained there, which exceeded –1°C in 2015 and 2025.

Analysis of annual precipitation totals at seven MC for the period 1945–2025 has shown that the values vary widely: the smallest totals have been characteristic of "Mineralnye Vody" MC (minimum 171 *mm*, average about 460 *mm*), and the largest – of "Kislovodsk" MC (maximum 1006 *mm*, average about 650 *mm*), with precipitation increasing from West to East. Synchronous wet years (1970, 1973, 1977, 1987, 1992, 2002, 2021) and dry periods (especially 1955, as well as 1998 and 2022–2025) have been observed at all stations, indicating common climatic mechanisms in the region (Fig. 6). No long-term sustained trend has been identified (the average correlation coefficient of the ratios of air temperature to precipitation at all stations (r) was approximately 0.24, with the relationship between atmospheric precipitation and temperature fluctuations being less than 6%).

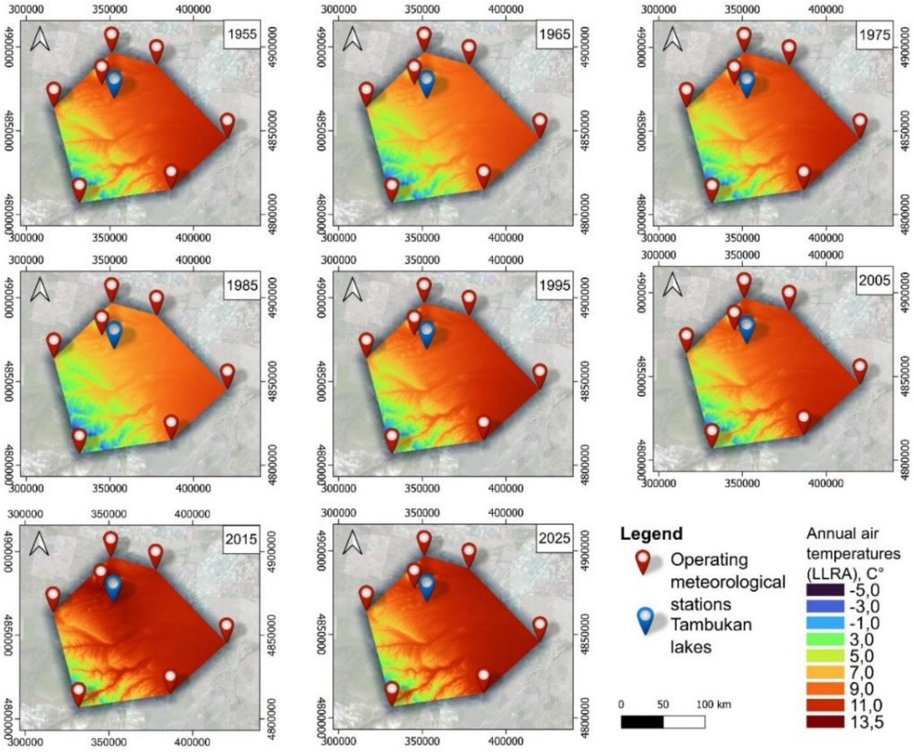

Fig. 5. Map of the distribution of average annual temperatures in the study area.

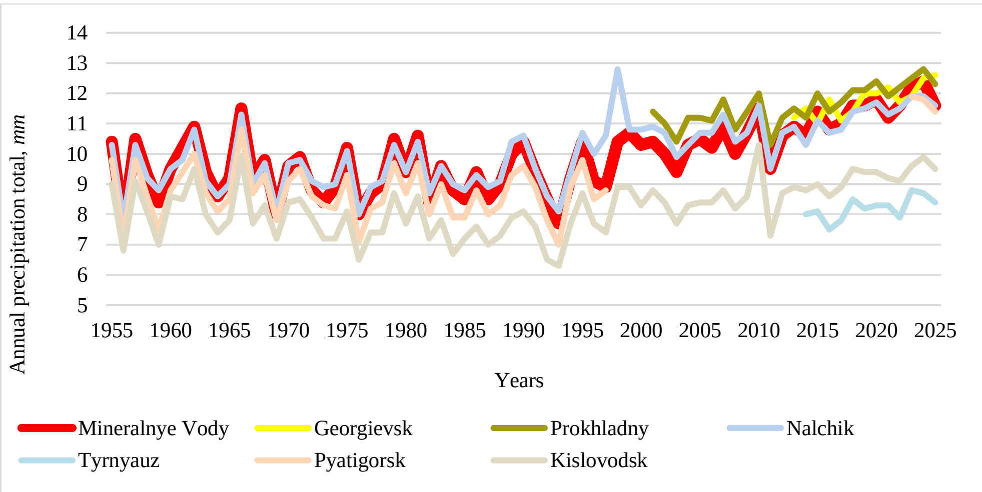

Fig. 6. Annual totals of atmospheric precipitation according to MC data.

According to the correlation analysis, for the "Mineralnye Vody" MC (series of average annual temperature and annual precipitation for 1955–2025), a correlation coefficient of $r = -0.21$ has been obtained (Fig. 7). According to the Chaddock scale, this value corresponds to a very weak negative relationship. The coefficient of determination ($r^2 \approx 0.043$) shows that only about 4% of the precipitation variability can be explained by temperature fluctuations.

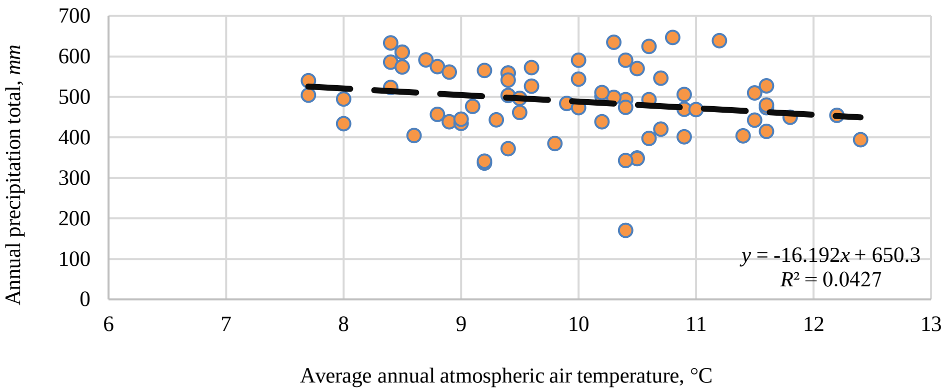

Fig. 7. Relationship between atmospheric air temperature and precipitation at the "Mineralnye Vody" MC.

Statistical testing at a significance level of $p < 0.05$ (critical value 0.22) gives $r < 0.22$; therefore, the identified correlation is not statistically significant – it may be random. This result is consistent with the climatic features of the Ciscaucasia region, where annual precipitation totals depend more on atmospheric circulation than on temperature.

It is important to note that the annual precipitation totals presented in this study are not intended to be reconstructed in the same manner as air temperature. Unlike the temperature lapse rate, the vertical gradient of precipitation is not linear. In the rugged terrain of Ciscaucasia, precipitation distribution is primarily governed by orographic barriers, slope aspect, and the direction of moisture-bearing airflows, rather than by elevation alone. Therefore, the LLRA method used in this study, which is based on linear elevation adjustment, cannot be applied to precipitation without developing a separate physiostatistical model. In this paper, precipitation data are analyzed to assess their long-term variability and to test the hypothesis of a possible relationship with temperature patterns. The absence of a significant correlation between precipitation and temperature series ($r = -0.21$, $p > 0.05$) only confirms that precipitation cannot be reconstructed from temperature analogues and requires a separate approach, which the authors intend to develop in future publications.

Conclusion. Comparison of the reduced average annual temperature series for Lake Tambukan with the data from the "Mineralnye Vody" MC has shown a high degree of agreement: the correlation coefficient was $r = 0.96$, RMSE was 0.8°C, and the maximum deviation did not exceed 1.2°C. This confirms the reliability of the applied interpolation method and the validity of using its results for selecting a reference station.

Due to the complexity of the relief and the peculiarities of air flow circulation in the area of Lake Bolshoy Tambukan, the spatial distribution of atmospheric precipitation cannot currently be considered a key reference point in forming an understanding of comparable reference values. For the same reason, the authors consider it inappropriate to apply the used interpolation method for atmospheric precipitation data to compare with values from other MC. Since, at present, the authors continue to work on studying the comparability of the analyzed data on total annual precipitation recorded at the MC under consideration with the nature of air mass transport in the area, the question remains open.

Thus, from the perspective of temperature indicators, the “Mineralnye Vody” meteorological station has proven to be a representative reference station for conducting research aimed at studying the formation of the water-salt balance of the Tambukan Lakes group.

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REFERENCES

1. Fedorov Yu.A. Hydrological and Hydrochemical Investigations Sulfide Lake Big Tambukan. *Science journal Bulletin of Higher Education Institutes North Caucasus Region Natural Sciences* **2** (2013), 81–88.
2. Shcherbakov V.N. Landscape of the Tambukan Depression. National Park “Kislovodsk” (2008).
3. Fedorov Y.A., Potapov E.G., et al. Features of Dynamics of Hydrological Parameters, Hydrochemical, Biogeochemical Indicators and Components of Brine and Sulfide Mud of Lake Bolshoy Tambukan. *Bulletin of Higher Educational Institutions. North Caucasus Region. Natural Sciences* (2002), 72–76.
4. Fedorov Yu.A., Garkusha D.N., et al. Methane and Hydrogen Sulphide in Sulphide Therapeutic Mud (on the Example of Lake Big Tambukan). *Science Journal Bulletin of Higher Education Institutes North Caucasus Region Natural Sciences* (2014), 102–109.
5. Fedorov Yu.A. Dynamics of Atmospheric Precipitation in the Therapeutic Sulfide Mud Deposits of Lake Bolshoy Tambukan. *Engineering Journal of Don* **4** (2017).
6. Güldenstädt I.A. *Journey through the Caucasus.* Diary Entries 1770–1773.
7. Haaz F.J. *My Trip to Alexander Waters* 1809–1810.
8. Potapenko Yu.Ya., Enna N.L. North Caucasian Regional Interdepartmental Stratigraphic Commission. Results of the Activities of Regional Interdepartmental Stratigraphic Commissions. Issue 39. St. Petersburg, Interdepartmental Stratigraphic Committee (2010), 18–28.
9. Fedorov Yu.A., Potapov E.G. Expeditionary Studies of the Tambukan Lakes within the Framework of the Russian Science Foundation (RSF) Project No. 17-17-01229 “Therapeutic Mud of the South of the European Territory of Russia: Formation Patterns, Assessment of Recreational Resources, and Development of a Monitoring System”. Southern Federal University (2018).
10. Report on Research Work under Civil Law Contract for the Implementation of Research Activities within the Federal Target Program “Development of the Water Management Complex of the Russian Federation in 2012–2020” No. 67-NIR/FTP-2016, May 10, 2016. St. Petersburg, (2016), 542.

11. Alisov B.A. *Climate of the USSR*. Moscow, MGU (1956), 127.
12. Reference and Information Portal "Weather and Climate". http://www.pogodaiklimat.ru/
13. Dodson R., Marks D. Daily Air Temperature Interpolated at High Spatial Resolution over a Large Mountainous Region: *Climate Research* **8** (1997), 1–20. https://doi.org/10.3354/cr008001
14. Lv Q., Sui M., et al. Preliminary Study on Near-Surface Air Temperature Lapse Rate Estimation and Its Spatiotemporal Distribution Characteristics in Beijing-Tianjin-Hebei Mountainous Region. *Remote Sens* **17** (2025), 2205. https://doi.org/10.3390/rs17132205
15. Pellicone G., Caloiero T., Guagliardi I. Understanding Trends in Near-Surface Air Temperature Lapse Rates in a Southern Mediterranean Region. *Climate* **14** (2026), 76. https://doi.org/10.3390/cli14040076

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ՏԱՄԲՈՒԿԱՆ ԼՃԵՐԻ ՏԱՐԱԾՔԻ ՕԴԵՐԵՎՈՒԹԱԲԱՆԱԿԱՆ ՑՈՒՑԱՆԻՇՆԵՐԻ ՎԵՐԼՈՒԾՈՒԹՅՈՒՆԸ՝ ՈՐՊԵՍ ԴՐԱՆՑ ՋՐԱԱՂԱՅԻՆ ՀԱՎԱՍԱՐԱԿՇՌՈՒԹՅԱՆ ՁԵՎԱՎՈՐՄԱՆ ՀԻՄՔ

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Տամբուկան լճերի շրջանում մասնագիտացված օդերևութաբանական կայանի բացակայության պատճառով հուսալի կլիմայական տվյալներ ստանալու համար անհրաժեշտ են այլընտրանքային մոտեցումներ: Այս ուսումնասիրությունը լուծում է այս բացը՝ օգտագործելով տարածական ինտերպոլյացիայի մեթոդներ: Մեթոդաբանությունն ավելի է բարդանում տարածաշրջանի բարդ տեղագրությամբ, որը զգալիորեն ազդում է տեղական ջերմաստիճանի բաշխման վրա: Այս հոդվածը ներկայացնում է Տամբուկան լճերի շրջանում օդի տարեկան միջին ջերմաստիճանների վերակառուցման արդյունքները՝ տեղական օդերևութաբանական կայանից տվյալների բացակայության պատճառով: LLRA (ուղղաձիգ ջերմաստիճանի գրադիենտի ուղղում) մեթոդի վրա հիմնված աշխարհագրական տեղեկատվական տեխնոլոգիաների, մոտակա յոթ օդերևութաբանական կայաններից (1955–2025 թթ.) դիտարկումների տվյալների և SRTM թվային բարձրության մոդելի միջոցով հաշվարկվել են լճերի համար ճշգրտված տարեկան միջին օդի ջերմաստիճանները: Ստացված արժեքների համեմատությունը Պիրսոնի կոռելյացիայի գործակցով օդերևութաբանական կայանների ցանցի տվյալների հետ ցույց է տվել ամենամեծ նմանությունը Միներալնիե Վոդի կայանի հետ: Հատկանշական է, որ վերլուծությունը ցույց է տալիս, որ լճերի և Միներալնիե Վոդի կայանի միջև համեմատաբար կարճ հեռավորությանը չնայած, համակարգված ջերմաստիճանային տարբերությունները պահպանվում են՝ պայմանավորված բարձրությամբ և տեղական միկրոկլիմայական պայմաններով: Այս հայտնագործությունը ընդգծում է բարձրության շտկումների կարևորությունը՝ կայանի հում տվյալների վրա հույսը դնելու փոխարեն: Մանրակրկիտ վերլուծությունը ցույց տալիս, որ Տամբուկան լճերի շրջանը

համակարգված ավելի ցուրտ է 0.74°C՝ 0.8°C ստանդարտ սխալով, որը համարվում է ընդունելի: Տարեկան տեղումները չեն օգտագործվել որպես հիմնական չափանիշ՝ Ցիկկովկասի բարդ տեղագրության պատճառով, որը ազդում է օդային զանգվածների տեղափոխման վրա: Հիմնավորված է Մինեռալնիե Վոդի կայանի տվյալների օգտագործման նպատակահարմարությունը լճերի ջրա-աղային հաշվեկշռի հետագա հաշվարկների համար:

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АНАЛИЗ МЕТЕОРОЛОГИЧЕСКИХ ПОКАЗАТЕЛЕЙ РАЙОНА ТАМБУКАНСКИХ ОЗЕР КАК ОСНОВА ДЛЯ ПОНИМАНИЯ ФОРМИРОВАНИЯ ИХ ВОДНО-СОЛЕВОГО БАЛАНСА

Резюме

Из-за отсутствия специализированной метеорологической станции в районе Тамбуканских озер для получения достоверных климатических данных требуются альтернативные подходы. Данное исследование восполняет этот пробел с применением методов пространственной интерполяции. Методология дополнительно усложняется из-за сложной топографии региона, которая существенно влияет на локальное распределение температур. В статье представлены результаты реконструкции среднегодовых температур воздуха в районе Тамбуканских озер, обусловленной отсутствием данных местной метеорологической станции (МС). С использованием геоинформационных технологий на основе метода LLRA (корректировка вертикального температурного градиента), данных наблюдений семи ближайших МС (1955–2025 гг.) и цифровой модели рельефа SRTM были рассчитаны скорректированные среднегодовые температуры воздуха для озер. Сравнение полученных значений с данными сети МС с применением коэффициента корреляции Пирсона выявило наибольшее сходство со станцией “Минеральные Воды”. Примечательно, что анализ показал: несмотря на относительно небольшое расстояние между озерами и МС “Минеральные Воды”, сохраняются систематические различия в температурах, обусловленные высотой над уровнем моря и местными микроклиматическими условиями. Этот вывод подчеркивает важность высотных поправок, а не использование сырых данных станции. Детальный анализ показал, что район Тамбуканских озер систематически холоднее на 0,74°C при среднеквадратической ошибке 0,8°C, что признано приемлемым. Годовые суммы осадков не использовались в качестве основного критерия из-за сложного рельефа Предкавказья, влияющего на перенос воздушных масс. Обоснована целесообразность использования данных МС “Минеральные Воды” для последующего расчета водно-солевого баланса озер.