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The analysis of the dependence of characteristics elements of snow on orography on the northeastern slope of the Greater Caucasus

Matanat Musayeva [1]
PhD (Geography), Associate Professor,
[1] Sumgait State University, Sumgait, Azerbaijan,
e-mail: musaeva.matanat@mail.ru, https://orcid.org/0009-0009-2609-5582;
Jamal Huseynov [2]
PhD (Geography), Senior Lecturer,
[2] National Aviation Academy, Azerbaijan Airlines JSC, Baku, Azerbaijan,
e-mail: camal_huseynov_88@mail.ru, https://orcid.org/0000-0002-7878-578X;
Mahmud Suleymanov [2]
PhD (Geography), Senior Lecturer,
e-mail: mahmud-suleymanov@mail.ru, https://orcid.org/0009-0009-0515-6737

ABSTRACT

Problem definition. Currently observed global warming is manifesting its effects, as in all regions, on the northeastern slope of the Greater Caucasus. Specifically, the increase in air temperature has caused changes in the elements of the snow cover in the area. The spatial-temporal distribution of snow cover elements, snow cover formation and melting dates, and changes in snow-covered days have been analyzed in the study area.

Formulation of the purpose. The research was conducted to determine the variation of snow cover elements depending on orography on the northeastern slope of the Greater Caucasus.

Research methods. During the analysis, stationary data on snow cover depth collected from 1964 to 2018 at the Khachmaz, Quba, Khaltan, Altiaghach, Giriz, and Khinalig hydrometeorological stations, as well as snow survey route data for the Gusarchay basin from 1986 to 2019, were used. The research was conducted using comparative and mathematical-statistical methods, along with the StokStat software. Here, the relationship between absolute elevation and snow cover duration was assessed, and it was determined that the number of snow-covered days exhibits greater persistence with increasing altitude.

The main material. The analysis determined that on the northeastern slope of the Greater Caucasus, in the period after 1990, while the height of the snow cover increased with rising air temperature, its density decreased. Furthermore, the formation and melting dates of the snow cover underwent variability compared to earlier years (before 1990). This process, as in all areas in recent years, is related to the increase in air temperature and changes in the zero isotherm in the study area.

Conclusions. The analysis established that in the upper zones, the passage of the zero isotherm is observed 15-20 days after the average snow cover formation date. In spring, it was determined that snow begins to melt 25-30 days after the temperature crosses zero degrees. On the northeastern slope above 1500 m, the average ten-day snow height varies between 10-25 cm, the maximum height between 15-30 cm, and the extreme height between 30-100 cm. The change in snow line elevation occurs intensively during winter, which is related to periodic temperature rises, with maximum snow height occurring in late February and early March. The research results can be used for water resource assessment, water management planning, and developing specific measures considering the impact of climate change on water resources.

Keywords: *snow characteristic elements, orography, snow cover, northeastern slope, variability of climatic factors, altitude, phenological characteristics of snow, sub-balance elements, snow reserves.*

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Problem definition. In modern climate change conditions, the characteristics of seasonal snow cover are changing significantly. In recent decades, as in many countries, in Azerbaijan the area of snow cover during transitional seasons is decreasing and its formation periods are shortening. However, the observed trends are often multidirectional and spatially heterogeneous [29, 31]. Additionally, recent research shows that when studying both temporal and spatial heterogeneity, discrepancies between main sources of snow cover data (ground-based, remote sensing, modeling) remain high.

In the study area, the most significant differences in measurements are observed between snow survey routes near meteorological stations, in open areas, and in forested areas. Snow accumulation coefficients are also decreasing - the ratio between snow reserves in forested and open areas is explained in some cases by the reduction in snow transported by snowstorms.

Snow survey observations along routes at HMS (Hydrometeorological Stations) represent the most important data source for studying long-term patterns and verifying other snow cover data sources (models, remote sensing). The use of different sources often yields divergent results when analyzing long-term trends. Snow cover observations at HMS are measurements taken only at specific near-by points, representing small areas with largely unknown characteristics. Observations at specific points may differ significantly from average values even in small river basins, and areas where values are close to average levels are randomly distributed.

Analysis of recent research. The formation of spring-summer river flows and the hydrograph pattern of high-water periods primarily depend on snow water equivalent. The study area's complex topography, with elevation varying across wide ranges and mountain ridges exposed to air masses of different humidity levels, creates conditions for complex spatial distribution of both snow cover and its water equivalent. To determine the role of snow cover in streamflow formation in northeastern slope rivers, multi-year snow survey route data were used. Research on spring flood formation and forecasting has examined the role of snow water reserves in basins, with assessments reflected in studies by S. Rustamov, V. Somaya, G. Khmaladze, A. Vajnov, Sh. Agayev, R. Mahmudov, M. Musayeva, J.S. Huseynov and other researchers.

Unlike previous authors, in this article the assessment of snow cover parameters for the study area is carried out using ground-based, remote sensing methods, and in recent years, various modeling methods used in America and some European countries to conduct a comparative analysis of basin and stationary observation data, taking into account the intra-annual and spatial (intra-basin) variability of snow cover parameters. The results reviewed here are in good agreement with studies assessing the representativeness of SNOTEL snow storage monitoring stations in North America for their surrounding areas [17, 18]. Only about half of the SNOTEL stations were shown to be within 10% of the average snow depth in their surrounding area. In addition, errors, as a rule, do not depend on the distance from the stations, but are associated with the characteristics of the surrounding area: absolute heights, insolation, and the nature of vegetation. Given the strong spatial heterogeneity of snow cover parameters and the limited use of point data, it is most optimal to use methods of assimilating data from various sources - ground, remote and model. A review of these methods is given in [8].

Highlighting previously unsolved parts. In recent years, rising air temperatures in high-altitude areas have led to decreased snow cover density and water content. Additionally, the elevation of the snow line during winter fluctuates sharply due to frequently recurring temperature increases. Such temperature rises can affect areas up to 2200-2300 m elevation, with diminishing impacts at higher zones.

Snow cover formation and melting dates have become more variable compared to previous years (pre-1990). This variability, observed recently across the study area as elsewhere, relates to shifts in the zero isotherm caused by rising air temperatures. Previous studies had not established relationships between absolute elevation and number of snow cover days. Moreover, due to insufficient data, the exact dependence of snow cover duration on increasing elevation remained unclarified in earlier research.

Formulation of the purpose. The main objective of the research is to study the dependence of the main parameters of snow cover on orography on the northeastern slope of the Greater Caucasus. Particular attention was paid to the variation of snow cover elements depending on altitude in the area. Taking into account the impact of changing climatic factors in the study area, the current state of the altitudinal variation characteristics of snow cover parameters was analyzed.

Research methods. The study area covers the northeastern slope of the Greater Caucasus, which is the highest mountainous region of Azerbaijan. The research utilized stationary snow depth data collected from 1964 to 2018 at the Khachmaz, Quba, Khaltan, Altiaghach, Giriz and Khinalig hydrometeorological stations of the National Hydrometeorology Department located on the northeastern slope of the Greater Caucasus, as well as snow survey route data from the Gusarchay basin for 1986-2019. The analysis of snow cover parameters is based on expedition data, long-term observational data and their comparison, application of mathematical-statistical methods, and the use of the StokStat software.

The main material. In lowland basins, interannual differences in winter snowfall, combined with varying intensities of snowstorm transport, cause an increase in discrepancies between stationary and basin data. Our research shows that our country has a tendency to increase the depth of snow cover, and the average trend of its maximum thickness is 0.8 cm per 10 years. Against the background of the tendency to increase the thickness of the snow cover, the duration of the formation of the snow cover, its density, humidity and the area occupied by the snow cover consistently decrease. On average, the decrease in the number of days with snow cover is -1.01 days/10 years. The most significant differences in the direction of trends are observed between measurements near meteorological stations, on snow measuring routes in open and forested areas [1,16,30]. Snow reserves also constantly decrease on forest routes (-1.19 mm/10 years). Snow accumulation coefficients also decrease, so the ratio of snow reserves in forested and open areas is partly explained by a decrease in the amount of "snow drift" (wind drift). Thus, the snow reserves measured in “open areas” (non-forest areas, according to the HMS data) are potentially close to the average snow reserves in open areas (along the route) in the river basin, and their relative errors of the average values were considered representative, less than 10%.

In any area, the formation of snow cover, its duration, melting intensity, distribution characteristics, and generally its role in river nourishment largely depend on complex physical-geographical factors, including the orographic features of the area [4, 11]. Taking this into account, the formation characteristics of snow cover at different elevations depending on vertical zonality were studied in the research area, and statistical analyses of stationary and special snow survey route data were conducted. To determine the variation characteristics of snow cover depending on altitude (comparatively for 1964-1990 and 1991-2018 [30], a graphical relationship (R=0.87, R=0.78) was established between absolute elevation and snow cover height (Figure 1). The deviation of some points from the main trend of the correlation curve is explained by the location characteristics of snow measurement points on slopes of different aspects in the area, and by the predominant influence of one or another factor. The correlation graph clearly demonstrates that snow cover height is greater in protected areas compared to open areas. However, the difference in snow cover height between these two areas is not uniform. The most significant difference is observed above the permanent snow cover zone (1000 m). The increase in snow cover height with elevation is not consistent across all zones, being most pronounced in mid- and high-mountain zones. On the northeastern slope, the snow cover is not particularly thick. In areas near the Caspian Sea, snow cover height reaches up to 10 cm.

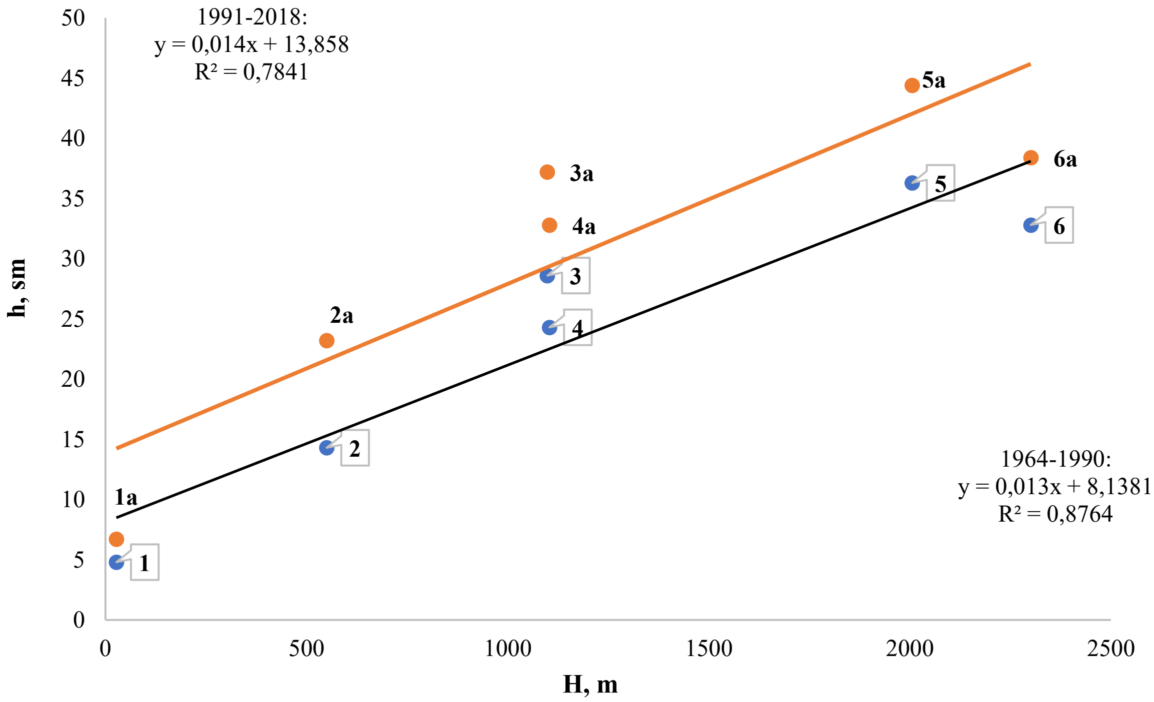

Fig. 1. Variation of snow cover height depending on elevation on the northeastern slope of the Greater Caucasus (1,1a-Khachmaz; 2,2a-Quba; 3,3a-Khaltan; 4,4a-Altıağac; 5, 5a-Qırız; 6, 6a-according to Khinaliq stationary data, "1-6" - winter precipitation of 1964-1990, "1a-6a" - winter precipitation of 1991-2018)

As seen in Figure 1, in the study area over the past 30 years, snow depth has increased compared to the period before 1990. With increasing elevation, snow cover thickness also increases. However, unlike the southern slope, this increase occurs much more slowly here. Up to 1500 m elevation, snow depth increases by 0.8 cm per 100 m; up to 2200 m this increase constitutes 2-3 cm. At higher elevations, the gradient reaches 5 cm. In the mid-mountain zone, at the meteorological station located at 1000-1200 m elevation, snow cover with a height of 10-12 cm predominates throughout the winter. At 1900-2000 m elevation, over the multi-year period, snow cover height shows minimal increase, varying between 15-20 cm. The absence of a clearly noticeable maximum at the Giriz high-mountain station is most likely related to the influence of the foehn wind. According to B. Pikhtinova (1958), the recurrence of foehn during the cold season is 103 days. The low snow cover height at this station can also be explained by the influence of the foehn present here [2, 3].

On the northeastern slope, despite generally low snow cover height, in certain extreme years its height can increase significantly. The maximum snow height on the northeastern slope is typically recorded between late December and early January. The average ten-day maximum snow height on the northeastern slope forms approximately 2 months earlier compared to the southern slope [15, 19]. This can be explained by the northeastern slope being more exposed to the influence of cold air masses arriving from the north.

Snow cover height increases with elevation. However, the rate of increase is not uniform across all elevation zones. In relatively lower zones, the increase is weak, while at higher elevations it becomes more intense. This is explained by the fact that with increasing elevation, due to temperature conditions, a greater portion of annual precipitation falls in solid form (snow) and winter duration lengthens.

The multi-year analysis of snow measurements taken along the route in March shows that in the Gusarchay basin, compared to previous years (before 1990), snow height (h, cm) has significantly increased across elevations, with only a slight decrease observed at 2020 m. It has been determined that during 1991-2019, snow height across elevations in this area was greater than during the pre-1990 period. However, while snow density was higher in the pre-1990 period, its water equivalent has relatively decreased in the post-1990 periods.

The timing of snow cover formation and melting varies depending on elevation. Specifically, persistent snow cover is observed at 3600-4000 m in mid-September, at 1900-2500 m in late October, and at 1500-1600 m in mid-November. At these elevations, the melting of persistent snow cover occurs in late June, early July, and February-March respectively.

In mountainous regions, the frequent recurrence of sub-zero temperatures prevents recently fallen snow from melting quickly. Thus, successive snowfalls accumulate layer upon layer, forming thick snow cover [1,10,16]. In high mountain zones, under unfrozen soil conditions, snow melting occurs due to solar radiation on the snow surface and the soil's own heat. Beginning in early spring, rising air temperatures intensify the snowmelt process. During this period, melting begins fastest in areas with lower snow density. The formation date of snow cover also changes with increasing elevation.

To determine the characteristic dependence of snow cover formation date on absolute elevation, a correlation graph was established between these two elements. The average snow cover formation date in the period after 1985 is delayed by several days compared to the months of the period before 1985. The snow cover formation and melting dates and duration are determined by the thermal regime of the area. As the number of days with negative temperatures increases, the number of snow-covered days also increases. This characteristic can be clearly seen from the graphs showing the changes in the zero isotherm and snow cover formation and melting dates depending on elevation (Figures 2-3).

In the foothill zone, snow cover formation and the zero isotherm hardly coincide. At higher elevations, the passage of the zero isotherm is observed 15-20 days after the average snow cover formation date. In spring, the opposite occurs: snow begins

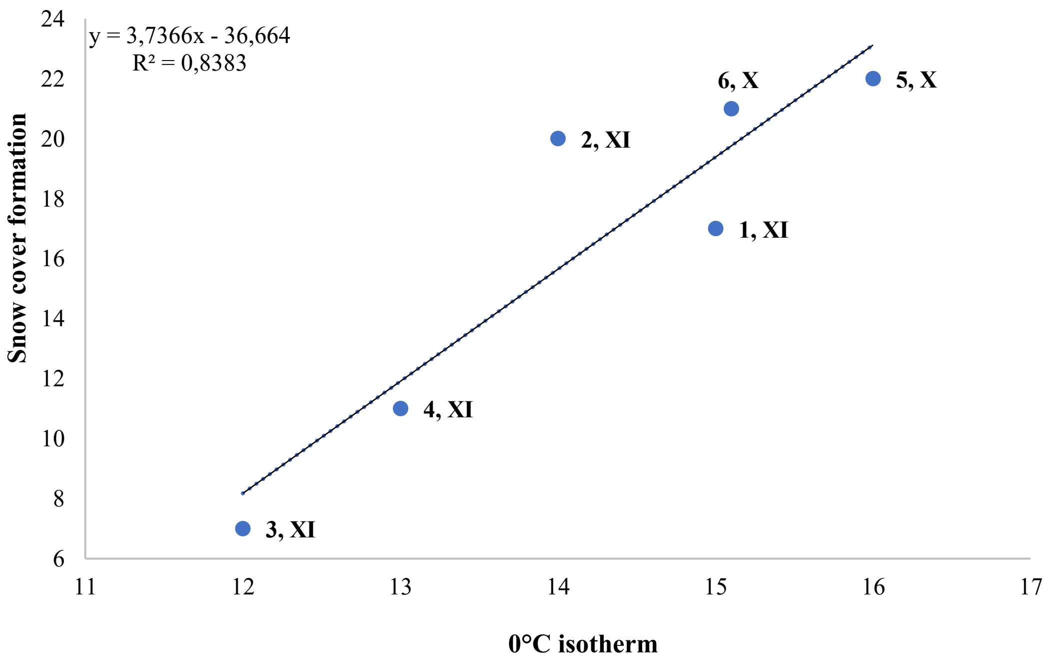

Fig. 2. Correlation graph between the zero isotherm and snow cover formation date (day of month) (1992-2018). *The graph shows:*
1-Altiaghach, **2**-Khaltan, **3**-Khachmaz, **4**-Guba, **6**-Giriz, **5**-Khinalig, **X**, **XI** - indicate months

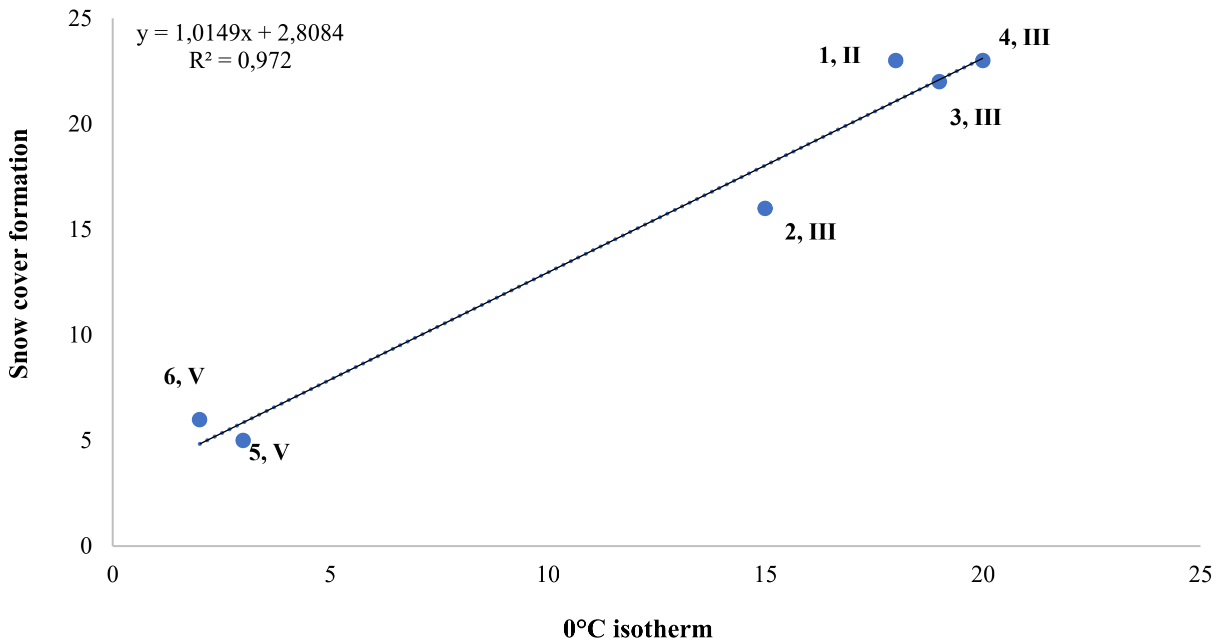

Fig. 3. Correlation graph between the zero isotherm and snow cover formation date (day of month) (1992-2018). *The graph shows:*
1-Giriz, **2**-Altiaghach, **3**-Khaltan, **4**-Khinalig**, 5**-Khachmaz, **6**-Guba, **II, III, V** - indicate months

melting 25-30 days after air temperature crosses above 0°C (Figure 4). On the northeastern slope's Shahdag, Tufan, and Babadag peaks, snow typically falls in early September [5, 9, 16].

In regions below this elevation, snow cover formation is gradually delayed due to higher temperatures. On the northeastern slope, exposed to cold air masses, snow cover forms earlier compared to the southern slope. At Giriz (2000 m), snow cover typically forms in the third 10-day period of October, while at 1000-1200 m elevation, it forms on November 1. In the mountains, as elevation increases, the snow cover formation period gradually decreases, averaging 2.5-3 months in mid-mountain zones and 2.5 months in high-mountain zones.

The snow cover melting process progresses from

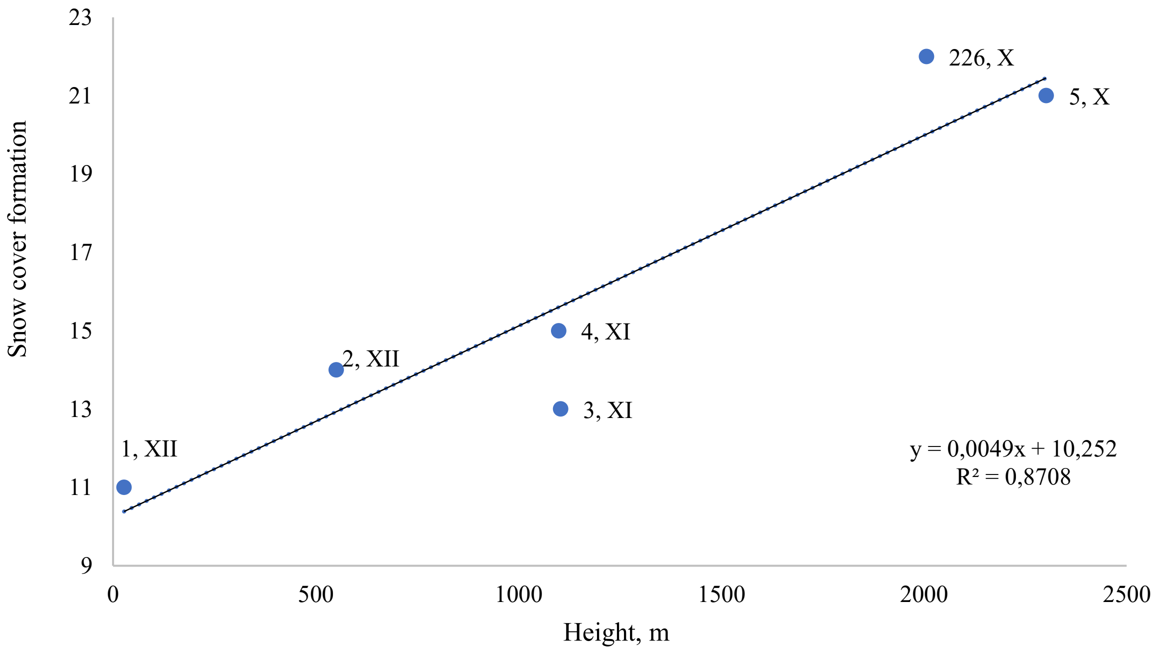

Fig. 4. Correlation graph between average snow cover formation date and absolute elevations (Long-term data: 27 m - Khachmaz, 550 m - Guba, 1099 m - Altiaghach, 1104 m - Khaltan, 2006 m - Giriz, 2301 m - Khinalig)

below (lowlands) upwards. Consequently, the snow melting date is delayed with increasing elevation.

The nature of surface cover plays a significant role in the snowmelt process. In forested areas, snow cover melts much later compared to non-forested areas. Snow cover melting concludes in lowland regions by late February to early March, and in foothill regions during March.

The elevation of the permanent snow line on the northeastern slope is 1000-1150 m. This is explained by the area being under the influence of cold air masses [2, 26, 28]. The lower boundary of permanent snow cover corresponds to the limit of unmelted snow cover lasting at least one month and is observed during most of the winter season. In mountainous regions, the timing of permanent snow cover formation mainly depends on the thermal regime and amount of winter precipitation. To demonstrate the variation characteristics of snow-covered days depending on thermal regime features, a correlation graph was established between these two elements. As seen from the correlation graph, the number of snow-covered days (N) increases with the number of days having average temperatures below 0°C (t). The equation of this relationship is given in Figure 5. N=0.8981t+1.3077 (1.1)

According to the equation (1.1), calculating the number of snow cover days requires only knowing the number of days with average temperature below 0°C. The quantity obtained by this method can be used for reporting purposes.

The analysis and research results have established the existence of a correlation curve between the number of snow cover days (*N*) and elevation (*H*) in the northeastern region of the Greater Caucasus. As seen from the correlation curve, snow cover duration increases with absolute elevation (Figure 6).

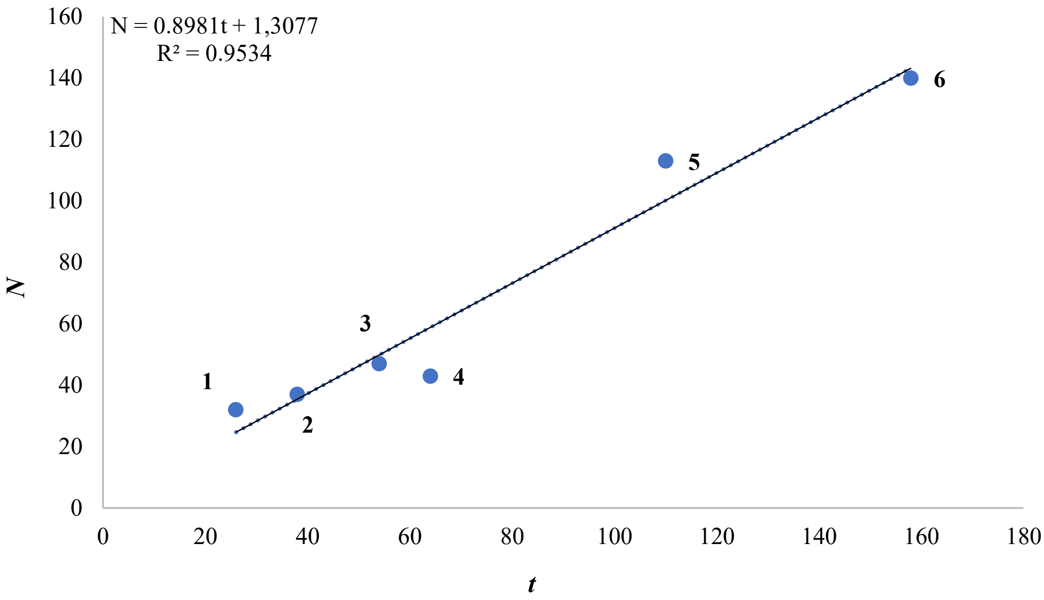

Fig. 5. Correlation between the number of snow cover days and the number of days with average temperature below 0°C in the northeastern region of the Greater Caucasus. *The graph shows:* **1**-Khachmaz, **2**-Guba, **3**-Altiaghach, **4**-Khaltan, **5**-Giriz, **6**-Khinalig; ***N*** **-** number of snow cover days, ***t*** **-** number of days with average temperature below 0°C

The analysis of graphs clearly shows that snow cover duration and maximum height vary depending on elevation and time. On the northeastern slope, where snow cover is less than on the southern slope, isohyets are drawn at intervals of 5 cm for average ten-day height, 10 cm for maximum height, and 25 cm for extreme height [14, 15, 29]. Above 1500 m on the northeastern slope, the average ten-day snow height ranges from 10-25 cm, maximum height from 15-30 cm, and extreme height from 30-100 cm.

To determine the influence of terrain roughness on snow cover elements in the area, comprehensive profiles were developed [4, 6]. These reflect corresponding variations along longitudinal profiles of snow survey routes. The average trend line of snow height variation closely matches the longitudinal profile of the route. Intensive increases in snow water equivalent are observed in zones where terrain roughness significantly increases. In zones with less terrain roughness, snow water equivalent increases only slightly with elevation. The uneven distribution of snow cover in Azerbaijan's territory is not always solely dependent on uneven precipitation distribution, absolute elevation, or terrain roughness. Undoubtedly, the uneven distribution of snow cover depends on wind speed, duration and direction, variable snowmelt intensity during periodic temperatu-

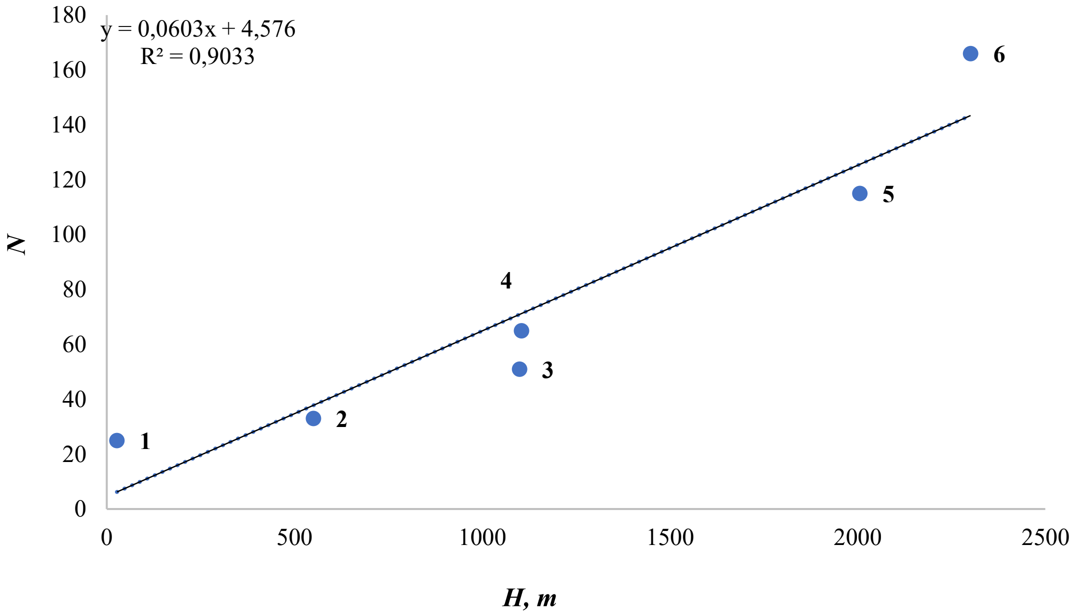

Fig. 6. Variation of snow cover duration depending on elevation on the northeastern slope of the Greater Caucasus (**1**-Khachmaz, **2**-Quba, **3**-Altiaghach, **4**-Khaltan, **5**- Giriz, **6**-Khinalig)

re increases, snow cover structure and thickness, vegetation cover, and other influencing factors [10, 12, 13].

The transport of soft and fresh snow from one place to another occurs when wind speed exceeds 2.4 m/s, and sometimes even 1.5 m/s. Snow cover is distributed more evenly in forested areas, which is related to reduced wind impact there. Therefore, the greatest snow height amplitude is observed in non-forested areas. In non-forested areas, the height amplitude varies between 10-20 cm. Here, the snow cover unevenness coefficient (K) fluctuates between 4.0-5.0.

Analysis of data obtained from snow survey routes shows that in forest zones, snow cover distribution is relatively uniform and changes gradually with increasing elevation. This pattern is clearly visible in the comprehensive diagram above. Fluctuations in snow height amplitude are more pronounced in non-forested areas. Above the forest zone (2200 m), the minimum snow height amplitude ranges 0.1-0.2 cm, while the maximum ranges 2.0-3.0 cm.

The variability of snow cover elements on the northeastern slope of the Greater Caucasus is explained by changes in physical-geographical, primarily meteorological factors. Due to variations in atmospheric elements - particularly air temperature and precipitation patterns - snow cover characteristics exhibit year-to-year variability [4, 7, 10, 20]. To quantify this variability, statistical parameters of snow cover characteristics were calculated for the study area using both snow survey route data and stationary snow measurement data.

In the study area, the coefficient of variation (C_v) of snow cover ranges between 0.40-0.73. To determine the altitudinal variation pattern of C_v and quantify its expression, a C_v=f(H) relationship was established. In relatively low-elevation areas, C_v changes intensively, while in high-elevation areas it changes gradually. In areas up to the foothill zone, the coefficient of variation ranges between 0.52-0.73, whereas in the permanent snow cover zone this value decreases to 0.46-0.40. This decrease in C_v results from the weakening influence of positive temperatures on snow cover formation with increasing elevation, causing the coefficient of variation values to fluctuate across a wider range in lower elevation areas.

The correlation curves based on snow survey route data also fully reflect this characteristic [23, 24]. Using these data, the variation coefficient of snow water equivalent (C_{vw}) was calculated. The variation coefficient of snow water equivalent follows the same altitudinal pattern [15]. However, in most cases, the C_{vw} value is smaller than the variation coefficient of snow depth (C_v).

The extreme value of the variation coefficient of snow water equivalent is greater than that of the variation coefficient of snow depth. Specifically, the C_v of snow water equivalent ranges between 0.34-0.92. The C_v of snow density has smaller values than those of snow depth and water equivalent, varying between 0.27-0.57. This characteristic was also identified in research conducted by M.Musayeva [15, 16].

Thus, while in previous years the northeastern slope was characterized by greater snow depth with relatively small density variations, in the last 30 years all three elements have undergone significant variability. The error for all three elements is determined by the following formula:

$$n=\frac{C_v^{\,2}10^4}{\sigma^2}; \qquad (1.2)$$

The asymmetry coefficient (Cs) is closely related to the variation coefficient (C_v). The established relationships for both parameters confirm this. These relationships were developed based on both stationary and snow survey route observation data. In most cases, the relationship showing the asymmetry coefficient and variation coefficient of snow density forms a second correlation that lies slightly above the general trend of points representing the variation coefficients of snow depth (C_v (h)) and snow water equivalent (C_v (w)).

In practical calculations, it is advisable to use the ratio Cs=2Cv, as this curve better fits the empirical data points. Calculating the variation coefficient allows determining different probability percentiles of snow cover characteristics. It should be noted that in practical applications, the 1% probability snow cover characteristics are most frequently used. The 1% probability snow depth exceeds the long-term average value by 2-4 times. For example, at Giriz station, while the average snow depth is 8.3 cm, the 1% probability value is 19 cm; similarly at Khaltan station, the 7.6 cm average corresponds to a 1% probability value of 19 cm. Based on snow survey route data, snow depths across elevations range 22-39 cm, while the 1% probability values reach 65-125 cm. These extreme values occur once every 100 years. The same pattern is observed for snow density. While the long-term average snow density in the Gusarchay basin ranges 0.21-0.26 g/cm³, the 1% probability value equals 0.32-0.47 g/cm³.

Regarding snow water equivalent, its average value ranges 45-101 mm. At 1% probability, this value varies between 110-440 mm.

Conclusions. In the northeastern slope of the Greater Caucasus under modern climate change conditions, the study of air temperature rise impacts on snow cover elements has yielded the following key results:

1. In the study area, due to rising air temperatures over the last 30 years compared to the pre-1990 period, snow height has increased while snow density has decreased.
2. Compared to previous periods, the zero isotherm passage now occurs 15-20 days after the average snow cover formation date (with a 3-4 day delay).
3. Currently, snow begins melting 25-30 days after air temperature crosses above 0°C (4-5 days earlier than in the pre-1990 period).
4. The study confirmed the existence of a correlation curve between the number of snow cover days and elevation in the research area.

For the first time in the northeastern slope of the Greater Caucasus, a comparative analysis of snow elements was conducted relative to the pre-1990 period, revealing changes in snow cover formation and melting dates in recent decades compared to earlier years, along with determining the elevation of the permanent snow line in recent years. Considering the study's results, they can be utilized in measures to mitigate the negative impacts of climate change on the area's snow-ice cover and water resources. Given that the melting of glaciers affected by climate change on higher peaks of the study area and changes in snow cover parameters will lead to water scarcity in the future, it is recommended to consider the research findings in developing preventive measures, particularly for forecasting river water availability. The use of this data holds significant importance for this region, which is considered a recreational area.

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Аналіз залежності характеристик елементів снігу від орографії на північно-східному схилі Великого Кавказу

Матанат Мусаєва [1]
д. філософії (географія), доцент,
[1] Сумгаїтський державний університет, Сумгаїт, Азербайджан;
Джамал Гусейнов [2]
д. філософії (географія), старший викладач,
[2] Національна авіаційна академія,
АТ «Азербайджанські авіалінії», Баку, Азербайджан;
Махмуд Сулейманов [2]
д. філософії (географія), старший викладач

Спостережуване наразі глобальне потепління проявляє свої наслідки, як і в усіх регіонах, на північно-східному схилі Великого Кавказу. Зокрема, підвищення температури повітря спричинило зміни елементів снігового покриву в цьому районі. Проаналізовано просторово-часовий розподіл елементів снігового покриву, дати формування та танення снігового покриву, а також зміни кількості снігових днів у досліджуваній зоні. Дослідження проводилося з метою визначення зміни елементів снігового покриву залежно від орографії на північно-східному схилі Великого Кавказу. Під час аналізу використовувалися стаціонарні дані про глибину снігового покриву, зібрані з 1964 по 2018 рік на гідрометеорологічних станціях Хачмаз, Куба, Халтан, Алтіагач, Гіріз та Хіналіг, а також дані маршрутів снігових досліджень для басейну Гусарчая з 1986 по 2019 рік. Дослідження проводилося з використанням порівняльних та математико-статистичних методів, а також програмного забезпечення StokStat. Тут було оцінено зв'язок між абсолютною висотою та тривалістю снігового покриву, і було встановлено, що кількість днів зі снігом демонструє більшу стійкість зі збільшенням висоти. Аналіз визначив, що на північно-східному схилі Великого Кавказу в період після 1990 року, хоча висота снігового покриву збільшувалася зі зростанням температури повітря, його щільність зменшувалася. Крім того, терміни формування та танення снігового покриву зазнали мінливості порівняно з попередніми роками (до 1990 року). Цей процес, як і в усіх районах останніми роками, пов'язаний зі зростанням температури повітря та зміною нульової ізотерми в досліджуваній зоні. Аналіз встановив, що у верхніх зонах проходження нульової ізотерми спостерігається через 15-20 днів після середньої дати формування снігового покриву. Навесні було визначено, що сніг починає танути через 25-30 днів після того, як температура перетне нуль градусів. На північно-східному схилі вище 1500 м середня декадна висота снігового покриву коливається в межах 10-25 см, максимальна висота - від 15-30 см, а екстремальна висота - від 30-100 см. Зміна висоти снігової лінії інтенсивно відбувається взимку, що пов'язано з періодичними підвищеннями температури, причому максимальна висота снігу припадає на кінець лютого та початок березня. Результати дослідження можуть бути використані для оцінки водних ресурсів, планування управління водними ресурсами та розробки конкретних заходів з урахуванням впливу зміни клімату на водні ресурси.

Ключові слова: *характерні елементи снігу, орографія, сніговий покрив, північно-східний схил, мінливість кліматичних факторів, висота, фенологічні характеристики снігу, елементи суббалансу, запаси снігу.*

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