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# ASSESSMENT OF CLIMATIC TREND OF AIR TEMPERATURE AT THE EARTH SURFACE IN THE CONTEXT OF STABLE DEVELOPMENT (CASE OF GYUMRI CITY)

***В. Г. Маргарян. ОЦЕНКА КЛИМАТИЧЕСКОГО ТРЕНДА ТЕМПЕРАТУРЫ ВОЗДУХА У ПОВЕРХНОСТИ ЗЕМЛИ В КОНТЕКСТЕ СТАБИЛЬНОГО РАЗВИТИЯ (НА ПРИМЕРЕ ГОРОДА ГЮМРИ).*** *Изучение и оценка колебаний температуры воздуха, в особенности в условиях ожидаемых изменений климата, приобретает особую актуальность и спешку. В то же время оценка временных изменений температуры воздуха важна как гарантия стабильного развития и залог перспективного развития экономики.*

*Целью данной работы является выяснить, проанализировать и оценить закономерности динамики изменения температуры воздуха в городе Гюмри.*

*Для решения этой задачи собраны, уточнены и проанализированы результаты фактических наблюдений за температурой воздуха метеостанции Гюмри, которые хранятся в фонде данных «Службы по гидрометеорологии и активному воздействию на атмосферные явления» МЧС Республики Армения. В процессе исследования проанализированы и уточнены соответствующие литературные источники, использованы математико-статистический, экстраполяционный, интерполяционный и корреляционный методы.*

*Получена многофакторная корреляционная связь между средней годовой температурой воздуха и абсолютным максимальным и минимальным значениями города Гюмри. Тесная корреляционная связь получена также между средними годовыми и экстремальными значениями температур приземного слоя воздуха и абсолютных максимальных и минимальных значений поверхности почвы города Гюмри. Это дает возможность рассчитать значение какой-либо характеристики температуры, имея другое. Отметим, что зимой средние значения температуры воздуха мало отличаются от средних значений температуры поверхности почвы. Эта разница растет и достигает максимума летом (июль-август).*

*В результате исследования выяснилось, что согласно фактическим данным температуры воздуха, в городе Гюмри наблюдается тенденция роста значений средних годовых и абсолютных максимальных температур воздуха, а абсолютных минимальных значений – тенденция понижения (в абсолютном смысле). То есть, на изучаемой территории в теплое время года ожидается рост засушливости и осушения климата, а в холодное время года – смягчение.*

*Такая закономерность присуща также другим регионам республики. Поэтому необходимо осуществление комплексных мероприятий по адаптации к последствиям изменения температуры воздуха, а также учесть это при разработке программ социального, экологического и экономического развития.*

***Ключевые слова****: температура воздуха, климатический тренд, динамика изменения, изменение климата, стабильное развитие, Гюмри.*

***В. Г. Маргарян. ОЦІНКА КЛІМАТИЧНОГО ТРЕНДУ ТЕМПЕРАТУРИ ПОВІТРЯ У ПОВЕРХНІ ЗЕМЛІ В КОНТЕКСТІ СТАЛОГО РОЗВИТКУ (НА ПРИКЛАДІ МІСТА ГЮМРІ).*** *Вивчення і оцінка коливань температури повітря, особливо в умовах очікуваних змін клімату, набуває особливої актуальності і поспіху. У той же час оцінка тимчасових змін температури повітря важлива як гарантія сталого розвитку й запоруки перспективного розвитку економіки.*

*Метою даної роботи є з'ясувати, проаналізувати і оцінити закономірності динаміки зміни температури повітря в місті Гюмрі.*

*Для вирішення цього завдання зібрані, уточнені і проаналізовані результати фактичних спостережень за температурою повітря метеостанції Гюмрі, які зберігаються у фонді даних «Служби по гідрометеорології та активному впливу на атмосферні явища» МНС Республіки Вірменія. У процесі дослідження проаналізовано та уточнено відповідні літературні джерела, використано математико-статистичний, екстраполяційний, інтерполяційний і кореляційний методи.*

*Отримано багатофакторний кореляційний зв'язок між середньою річною температурою повітря і абсолютним максимальним і мінімальним значеннями міста Гюмрі. Тісний кореляційний зв'язок отримано також між середніми річними і екстремальними значеннями температур приземного шару повітря і абсолютними максимальними і мінімальними значеннями поверхні ґрунту міста Гюмрі. Це дає можливість розрахувати значення будь-якої характеристики температури, маючи інше. Відзначимо, що взимку середні значення температури повітря мало відрізняються від середніх значень температури поверхні ґрунту. Ця різниця зростає і досягає максимуму влітку (липень-серпень).*

*В результаті дослідження з'ясувалося, що згідно з фактичними даними температури повітря, в місті Гюмрі спостерігається тенденція зростання значень середніх річних і абсолютних максимальних температур повітря, а абсолютних мінімальних значень – тенденція зниження (в абсолютному значенні). Тобто, на території, що вивчається, в теплу пору року очікується зростання посушливості і осушення клімату, а в холодну пору року – пом'якшення.*

*Така закономірність властива також іншим регіонам республіки. Тому необхідне здійснення комплексних заходів щодо адаптації до наслідків зміни температури повітря, а також врахувати це при розробці програм соціального, екологічного та економічного розвитку.*

***Ключові слова****: температура повітря, кліматичний тренд, динаміка зміни, зміни клімату, сталий розвиток, Гюмрі.*

### Introduction

Air temperature characterizes the state of one of the climate system's components - the atmosphere. This is determined by the peculiarities of solar energy distribution on the earth's surface, processes of interaction between the connections of the climatic system. The role of air temperature is very important in the formation of runoff, evaporation, in the formation and disappearance of ice phenomena, in heat and moisture circulation, as well as during

frosts, droughts and desertification. The role of the thermal regime is vital in water consumption and crop production.

Therefore, the identification and assessment patterns of temporal air temperature distribution is of particular importance, especially in water balance, the effective use of thermal resources.

Therefore, taking into account the above, the purpose of the work was to identify, analyze and evaluate patterns of dynamics change of the air temperature of Gyumri city.

To solve the suggested problems appropriate researches [2, 6-7, 13, 17-18, 20-21] have been used as a theoretical base. As the source material – the actual data of long-term observations of the air temperature of the Gyumri weather station, stored in the funds of the Ministry of Emergency Situations of the Republic of Armenia «Service for hydrometeorology and active influence on atmospheric phenom-

ena». As a methodological basis the following methods were applied in the work: complex, mathematical-statistical, geographical, correlation, extrapolation, analysis.

**Study area**

Gyumri weather station is located in the regional center of Shirak marz of the Republic of Armenia, in Gyumri city, at an altitude of 1523 m (Fig. 1). By population (119.9 thousand inhabitants, as of January 1, 2014) and by its significance it continues to be considered the second city of Armenia, after the capital Yerevan. The western part of the city is high, consisting of two heights, table shaped. The relief is flat, slightly dissected, covered with lake-river and volcanic sediments 300-350 m thick located in the 8-9 points seismic zone. The Gyumri, Jajur and Cherkez small rivers flow through the territory of Gyumri.

Gyumri is located in the northern part of the



Fig. 1. Location of Gyumri city in the Shirak region

Shirak plain, on the left bank of the Akhurian River, originating from Lake Arpi. It is located at a distance of 118 km from Yerevan,the height above sea level is about 1550 m. The Shirak plain is surrounded by the Pambak mountain range from northeast, east and southeast, its mountain spurs are 52-100 m from the meteorological area, exceeding its height by 200-500 m. Mountain Aragats (4090 m) lies in

the northeast area, at a distance of about 40 km. All surrounding mountains are covered with grassy vegetation.

Gyumri meteorological station was founded in 1843, where continuous meteorological observations have been carried out since 1893. However, in 1961, the place of the meteorological area was changed, as a result of which the uniformity of

number of observations was disturbed. Thus, in the paper, the actual data of air temperature observations from 1961-2018 are discussed and analyzed.

**Results**

The paper collected and processed the results of actual observations of the air temperature of Gyumri weather station, which are summarized in Table 1.

In general, the climate of Gyumri is continental with relatively warm summers and cold winters. The average amplitude of the annual fluctuations in air temperature is 23.2-35.8 °C, the absolute amplitude is 50.8-68.9 °C. In winter there are sometimes severe frosts, the minimum temperature can drop to -36.0. The winter is snowy and cold and lasts from December to March inclusive. Spring is short and cool. It lasts only 1.5 months. Summer is relatively warm, from the beginning of June to the end of September. Autumn stands out for its warmth. Autumn months are warmer than spring months. This is an important feature of the thermal regime not only of the study area, but also of the republic. The reason is that in spring there is still snow cover. Snow melts, it is cloudy and precipitation is heavy. The number of sunny days per year in Gyumri is the biggest in the republic. The average annual rainfall is 340-736 mm (average 500 mm).

In the study area, the warmest months are July-August, with an average monthly air temperature of 19.9, and coldest one is January, with an average monthly air temperature of – 8.56 (Table 1). According to the average annual air temperature in Gyumri, the coldest year was 1973, and the warmest year was 2018. It is necessary to note that 2010, 2018 were also the warmest years in Armenia for the entire period of observation.

The absolute minimum air temperature for the entire observation period was recorded on January 21 1972 and was -36.0 °C, the absolute maximum value was recorded on July 9 1986 and was 38.0 °C.

Thus, during the year there is a well pronounced course of average absolute maximum and minimum air temperature values (fig. 2). During the year, according to the actual daily average data, the monthly average maximum values are observed in July, and the minimum values – in January. In some years, the lowest average monthly air temperature can also be observed in December or February. Sometimes there may be years when equal values of mean monthly air temperature are observed in July and August during the year. The average minimum and average maximum values of air temperature also have a well-defined inter-annual distribution: minimum values are observed in January, maximum values – in July-August.

A multi-factorial correlation relationship (correlation $R=0,68$) between the average annual air temperature ($\overline{T}$) and absolute maximum ($T_{\max}$) and absolute minimum ($T_{\min}$) values of Gyumri city was obtained. This relationship can be expressed as the following equation:

$$\overline{T} = 0,17T_{\max} + 0,15T_{\min} + 4,71.$$

This will make it possible to pre-calculate the average annual air temperature, having absolute maximum and minimum values.

*Table 1*

Monthly and annual average and extreme values of air temperature
At the meteorological station of Gyumri

| **Months** | | | | | | | | | | | | **Year** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **I** | **II** | **III** | **IV** | **V** | **VI** | **VII** | **VIII** | **IX** | **X** | **XI** | **XII** | |
| **Average** | | | | | | | | | | | | |
| -8.56 | -6.97 | -0.12 | 7.01 | 11.7 | 15.9 | 19.9 | 19.8 | 15.6 | 8.89 | 1.79 | -4.97 | 6,66 |
| **Average maximum** | | | | | | | | | | | | |
| -1.92 | 0.31 | 5.74 | 10.4 | 13.7 | 19.8 | 23.6 | 23.3 | 19.2 | 11.3 | 5.34 | 1.20 | 9,62 |
| **Average minimum** | | | | | | | | | | | | |
| -15.7 | -14.5 | -6.20 | 3.40 | 9.14 | 13.1 | 16.9 | 16.8 | 12.7 | 4.04 | -3.31 | -11.7 | 4,66 |
| **Absolute maximum** | | | | | | | | | | | | |
| 9.20 | 14.0 | 21.5 | 26.8 | 29.3 | 33.1 | 38.0 | 37.0 | 35.1 | 27.4 | 19.6 | 17.6 | 38,0 |
| **Average absolute maximum** | | | | | | | | | | | | |
| 3.78 | 6.02 | 14.0 | 21.0 | 24.7 | 29.0 | 32.6 | 32.7 | 29.7 | 23.7 | 15.4 | 7.80 | 33.5 |
| **Absolute minimum** | | | | | | | | | | | | |
| -36,0 | -35,0 | -27,7 | -16,0 | -7,60 | -3,60 | 0,30 | 1,90 | -3,70 | -12,5 | -23,0 | -30,0 | -36,0 |
| **Average absolute minimum** | | | | | | | | | | | | |
| -24.1 | -22.9 | -16.2 | -6.52 | -0.85 | 3.06 | 6.98 | 7.04 | 1.51 | -4.74 | -12.0 | -20.1 | -26.4 |
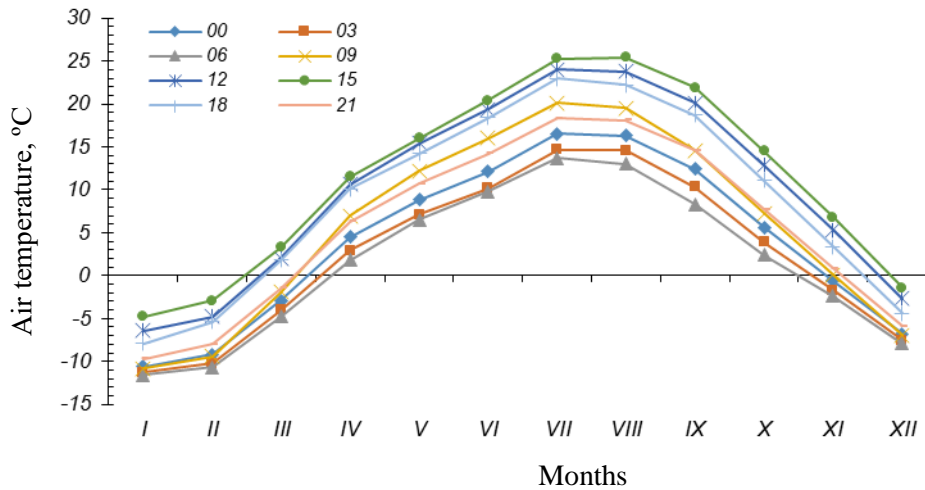
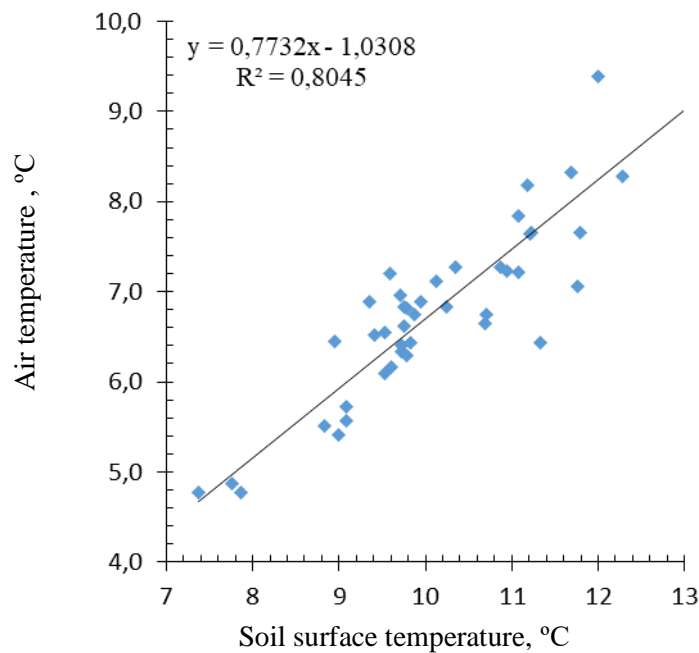Fig. 2. Annual course of air temperature observed at the meteorological station of Gyumri



Fig. 3. Correlation link between average annual values of air and soil surface temperature

A close correlation relationship (correlation $R = 0,90$) was also obtained between the air temperature of the surface layer of the atmosphere and the average annual values of the soil surface temperature of Gyumri city (Fig. 3). This will make it possible to calculate the value of any temperature characteristic, having a value of the other. Close correlations are also obtained between the extreme values of air and soil temperatures. This type of dependency is obtained both for individual regions of the republic and for its entire territory. Note that in winter, the average air temperature values differ little from the average temperature of the soil surface. This difference grows and reaches its maximum in summer (July-August).

It is very important to know periods of the average daily temperature transition through certain limits (0, 5, 10, 15 °C) for different sectors of the economy, in particular, agriculture in spring and autumn, the number of days with these values and their sum. This determines possibility to cultivate a particular crop in a given place. For most agricultural crops, the active growing season begins during the period of average daily temperatures above 10.0 °C. The annual total of active temperatures above 10.0 °C is taken as an indicator of the heat supply of the growing season (Table 2). In the study area this period is on average observed from the beginning of May to the first decade of October and lasts 157 days.

As a result of the research, it has turned out that there is a tendency of growth of average annual and extreme (absolute maximum) values in the air temperature of Gyumri city (Fig. 4, 5). We note that this pattern is also characteristic of other regions of the republic and the world. [1, 3-5, 8-12, 14-16, 21].

The dynamics of changes in the air temperature of Gyumri city in a monthly section was also studied. It shows dynamics of changes in the values of average annual and absolute maximum monthly air temperature, characterized by a tendency of growth except the values of December. As for the values of absolute minimum monthly air temperatures, it should be noted that with the exception of April, there is a tendency of monthly values growth for all other months. This means that in Gyumri, in the warm period of the year an increase in aridity and climate drainage is expected in the region, in the cold period of the year – mitigation, and in December – an increase in severe weather. We note that in the study area there is also a tendency of growth in the annual values of heat indices.

These changes will have an inevitable consequence on the change in the components of the hydrothermal balance of the study area, imbalance of ecosystems, as well as on the social, ecological and economic development of the city. Therefore, an ecosystem approach should be adaped to this change in air temperature and to implement integrated adaptation measures to mitigate the effects of change.

The paper attempts to determine the average annual air temperature values of the city of Gyumri in 2030, 2070 ad 2100 using the extrapolation method. As a result, it has turned out that if the move above the indicated change continues, the average annual value of air temperature will increase compared to the current norm: in 2030 - 0,09 ºC (1,37 %), in 2050 - 0,27 ºC (4,12 %), in 2070 - 0,48 ºC (7,32 %), in 2100 - 0,85 ºC (13 %).

In Gyumri city we have a stocking factory, sugar and beer factories. «Gyumri», «Alexandrapol» beer factories, «Lusastgt Shugre» Armenian-American building units and etc.are also known here. It means that the increase in air temperature in Gyumri is mainly due to the microclimatic and local features of city. So, in order to reduce or prevent further increase in air temperature, it is very important to plant a green area and create small pools. On the other hand, it is necessary to monitor the implementation and preservation of these works.

Changes in air temperature and precipitation in Armenia are estimated for different periods, and results of which are used in the first, second and third national communications of the Climate Change of Armenia [15-16]. The results show that over the past decades there has been a significant increase in air temperature in Armenia. Moreover, in 1935-96 in relation to the base period (1961-1990) the average annual temperature increased by 0.4 ºC, in 1935-2007 period - by 0.85 ºC, in 1935-2012 - by 1.03 ºC. These results show that temperature increases significantly. Since 1994, deviations of average annual temperatures compared with the average for 1961-1990 were only positive.

*Table 2*

Total average daily temperatures through 0; 5,0; 10,0; 15,0 ºC in spring
and autumn, the increasing order

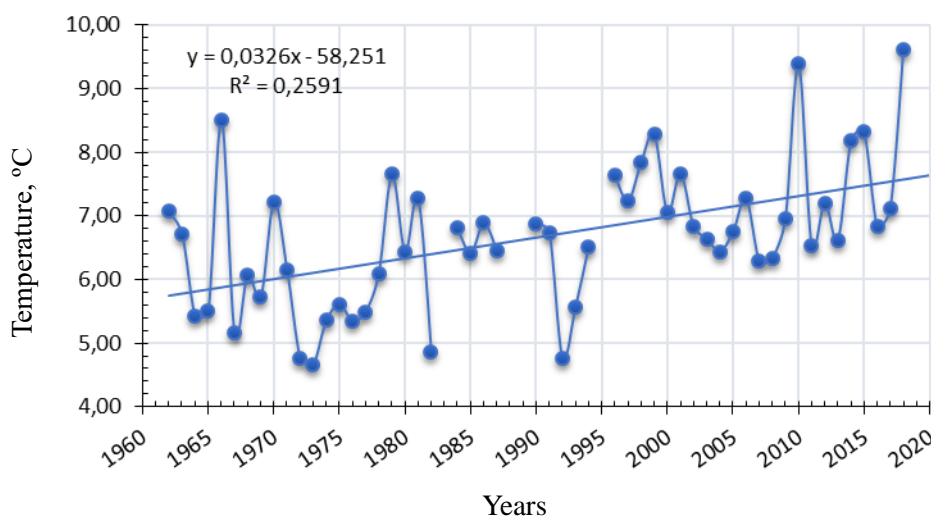| Air temperature, ºC | Months | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
| 0,0 | | | 12 | 206 | 566 | 1022 | 1618 | 2213 | 2661 | 2919 | 2982 | |
| 5,0 | | | | 156 | 516 | 972 | 1568 | 2164 | 2612 | 2869 | | |
| 10,0 | | | | | 314 | 770 | 1366 | 1962 | 2409 | 2642 | | |
| 15,0 | | | | | | 568 | 863 | 1459 | 1661 | | | |



Fig. 4. Dynamic change of average annual values of air temperature in Gyumri
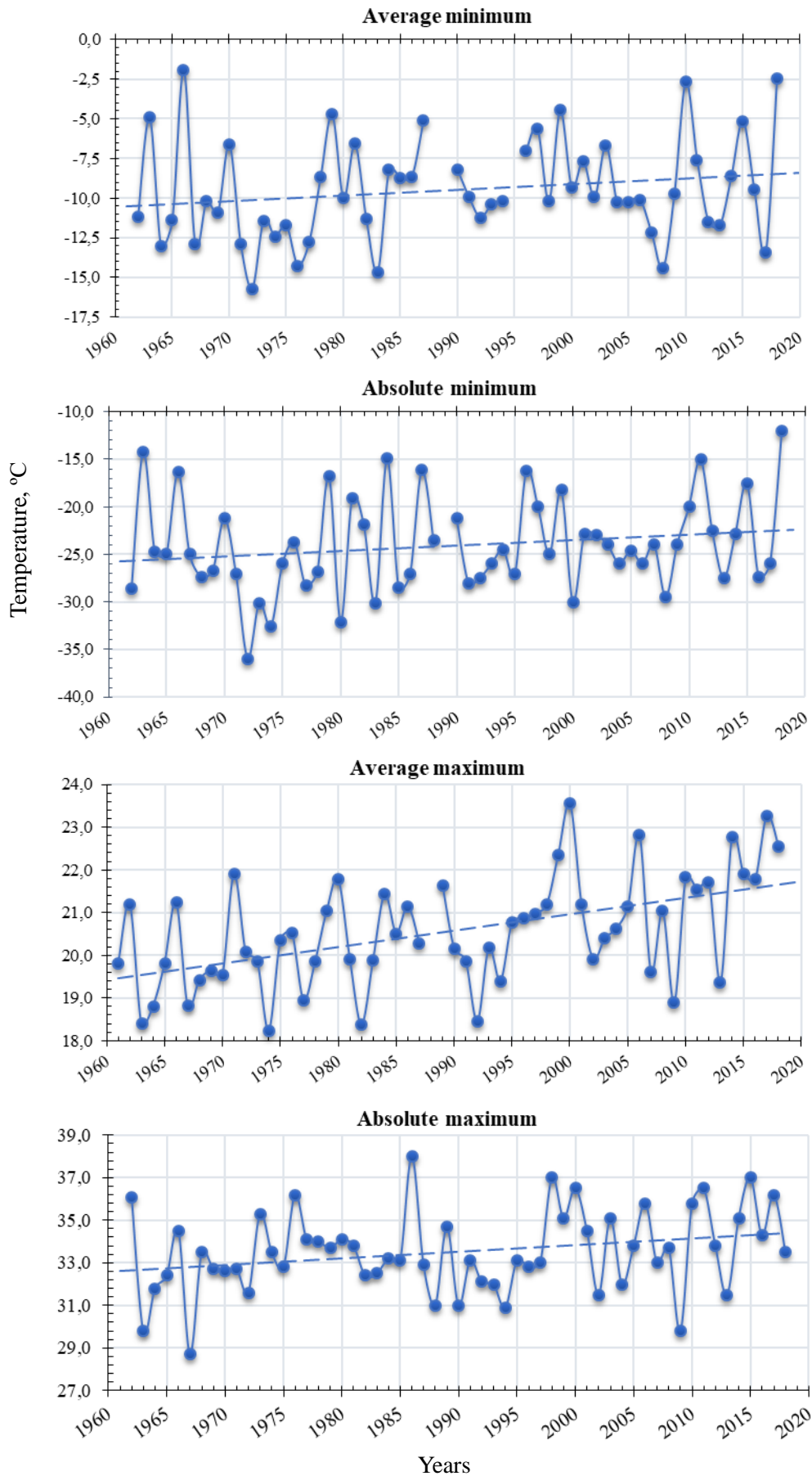
Fig. 5. Dynamic change of average annual minimum and maximum, absolute minimum and absolute maximum of air temperature in Gyumri
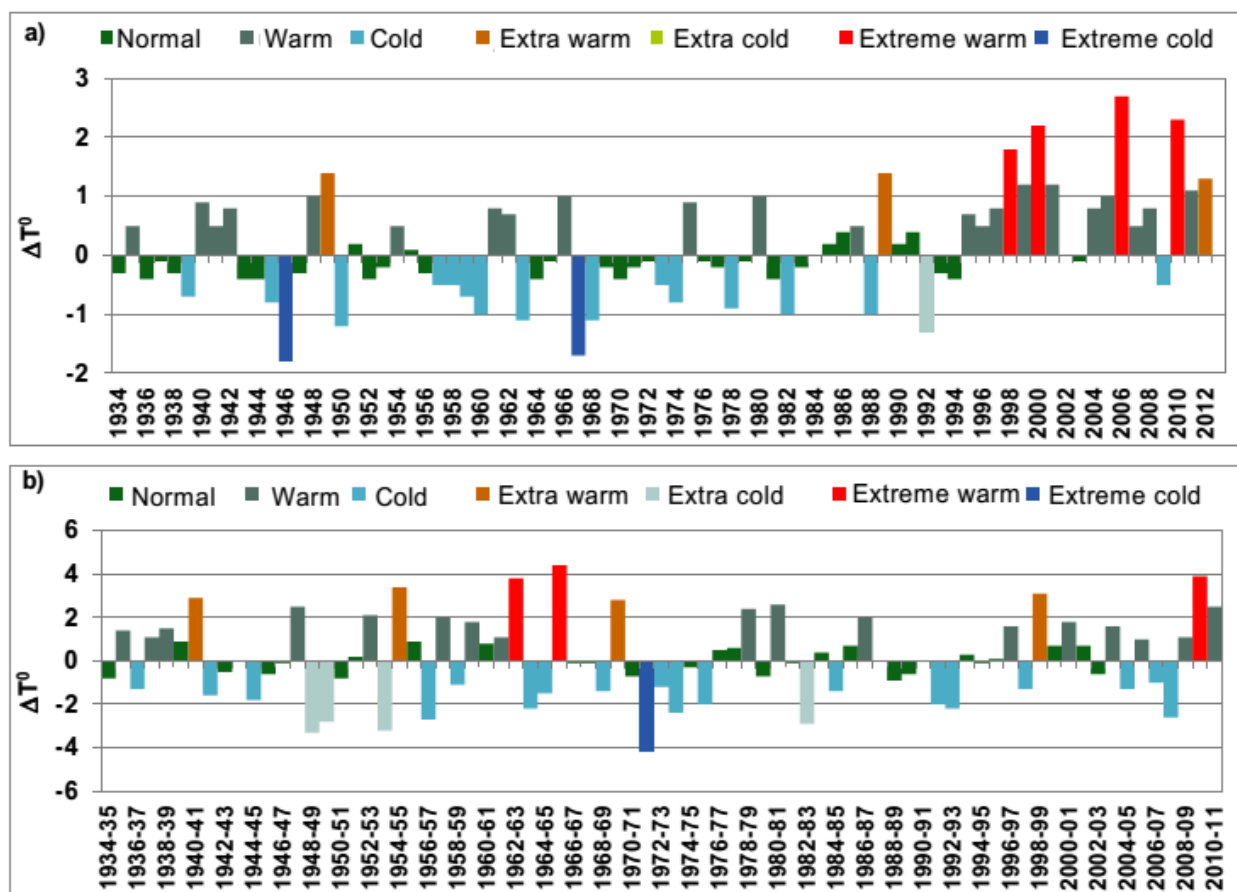
Fig. 6. Deviation of summer (a) and winter (b) temperatures in the territory of Armenia in 1935-2012 from the average values for 1961-1990 [15].

Over various seasons of the year ambient air temperature changes exhibit different trends. In 1935-2011 the summer average temperature increased by about 1.1 ºC, and extremely hot summers have been observed over the last 17 years (1998, 2000, 2006, 2010) (Fig. 6a). Winter temperature changes look different: seasonal mean temperature increases are insignificant at 0.40C (Fig. 6b) [15].

The regional climate model allows to obtain more detailed information on climate in the regional scale. It is the Hadley Centre model HadRM3P, identical with the regional climate model (RCM) used within PRECIS with horizontal resolution 0.22º x 0.22º (25 x 25 km). It uses data from the HadAM3P atmosphere-only global model to provide its lateral boundary conditions. The HadRM3P model simulation output data for the baseline period of 1961-1990 and the future projections of the climate (2071-2100) for A2 emission scenario have been studied in detail. Averaged results of the forecasts for Shirak, made with MAGICC/SCENGEN computer software, are presented in Tab. 3. Significant and continuous increase in temperature is forecasted by both various GCMs, as well as by the aggregate mean. All GCMs indicate exceptional warming throughout the year: the increase in tem-

perature is somewhat higher in hot months of the year, as compared to the cold ones, thus underlining the trend of continuous increase, if not intensification, from the one observed in Armenia during the 20th century [19].

Temperature changes in different regions of the territory of the Republic of Armenia and in different seasons have different tendency. Table 3 shows changes in seasonal and annual temperatures compared to the average for 1961-1990, according to PRECIS model under A2 scenario of IPCC in Shirak [19].

However, according to our research, the indicated values of the air temperature change are rather higher than the values of the expected air temperature change in Gyumri. Therefore, the assessment and management of dynamic changes in air temperature as well as the processing of mitigation parts, need to be done locally, especially in mountainous countries.

**Conclusions**

Thus, the research results have led to the following conclusions and suggestions:

- The features and patterns of the spatial- temporal distribution of air temperature are caused by

*Table 3*

Changes in seasonal and annual temperatures (°C) compared to the average
for 1961-1990, according to PRECIS model under A2 scenario of IPCC [19]

| Winter | Spring | Summer | Autumn | Annual |
|--------|--------|--------|--------|--------|
| **2030** | | | | |
| 1 | 1 | 1 | 1 | 1 |
| **2070** | | | | |
| 3 | 3 | 3 | 3 | 3 |
| **2100** | | | | |
| 3-5 | 3-5 | 3-6 | 4-6 | 4-6 |

the complex effect of physical-geographic and anthropogenic factors;

- In a number of long-term data, there is a tendency of average annual and extreme values of air temperature growth;

- Despite many studies that have been done, so far there are no systematic studies to identify the causes of changes in air temperature and the available ones concern only its individual aspects. So, it is advisable to continue systematic and comprehensive research and develop further forecasts using new models;

- assessing the tasks of changing air temperature will get the right decision in the event that it reveals the connections with other components of the complex natural space under conditions of direct human exposure.

It is necessary to:

- re-equip Gyumri weather station with modern equipment (especially automatic);

- raise public awareness of climate change and its effects;

- assess ecosystem's vulnerability due to changes in air temperature;

- implement organizational, legal, institutional, technical measures to mitigate the effects of climate change and adapt the economy to new environmental condition;

- strengthen scientific studies of climatic problems and introduce new technologies;

- develop real climate scenarios;

- develop programs of measures aimed at mitigating the negative effects of changes in air temperature;

- finance sufficient implementations by the state and foreign donor organizations The implementations made should be transparent to society, aimed at some specific programs and monitored by disinterested bodies;

- develop and implement advanced training programs, periodic organization of educational processes, professionally develop specialists;

- implement and provide international scientific and educational cooperation, strengthening interdepartmental cooperation.

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## ASSESSMENT OF CLIMATIC TREND OF AIR TEMPERATURE AT THE EARTH SURFACE IN THE CONTEXT OF STABLE DEVELOPMENT (CASE OF GYUMRI CITY)

**Formulation of the problem.** The study and assessment of air temperature fluctuations, especially in conditions of expected climate change, is of particular relevance and haste. At the same time, the assessment of temporary changes in air temperature is important as a guarantee of stable development and a long-term economic development.

**The purpose of the article.** The purpose of this work is to find out, analyze and evaluate the patterns of the dynamic changes in air temperature in Gyumri city.

To solve this problem, the results of actual observations of the air temperature of the Gyumri weather station, stored at the Ministry of Emergency Situations of the Republic of Armenia «Service for Hydrometeorology and active influence on atmospheric phenomena» have been collected, refined and analyzed.

**Methods**. In the course of research we analyzed and clarified appropriate literary sources, using mathematical-statistical, extrapolation, complex, analyze and correlation methods.

**Results.** A multifactorial correlation relationship was obtained between the average annual air temperature and its absolute maximum and minimum values of Gyumri city. A close correlation was also obtained between the average annual air temperature and its absolute maximum and minimum values of Gyumri city, between the average annual and extreme values of the surface air temperature and the absolute maximum and minimum values of the soil surface of Gyumri city. This makes it possible to calculate the value of any temperature characteristic, while having the other one. Note that in winter the average air temperature values do not differ much from the average soil surface temperature values. This difference grows and reaches its maximum in summer (July – August).

As a result of the research, it turned out that according to the actual data on the air temperature in Gyumri city, there was a tendency for the average annual values and absolute maximum of the air temperature to rise, while the absolute minimum values showed a downward trend (in the absolute sense). That is, in the study area in the warm season, an increase in aridity is expected on climate drainage, and in the cold season – a softening.

In the work we tried to define the monthly average values of air temperature in Gyumri in 2030, 2070, 2100, using the extrapolation method. The result shows that if the changing process continues, the annual average values of air temperature will increase with comparison to current normal: in 2030 – 0.09 ºC (1.37 %), in 2050 – 0.27 ºC (4.12 %), in 2070 – 0.48 ºC (7.32 %), in 2100 – 0.85 ºC (13 %).

This pattern is also characteristic of other regions of the republic. Therefore, it is necessary to implement integrated measures to adapt to the effects of air temperature changes and take this into account when working out programs for social, environmental and economic development.

**Keywords:** air temperature, change in dynamics, climatic trend, stable development, Gyumri.

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