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Changeability the Monthly Mean Values of Air Effective Temperature on Missenard in Batumi in 1956-2015

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ABSTRACT

Results of a statistical analysis of monthly average of the values of air effective temperature on Missenard (ET) in Batumi from 1956 to 2015 are presented. The intra-annual distribution of ET values in three time periods was studied: 1956-1985, 1956-2015, 1986-2015; their repetition of occurrence by ET categories in the specified time periods was obtained, etc. The influence of climate change on ET values was revealed.
In particular, it is shown that in 1986-2015, compared with 1956-1985, the repetition of ET values for the category "Very cold" decreased from 1.7% to 1.1%, "Cold" - decreased from 23.9% to 22.8%, "Cool" - increased from 35.0% to 35.8%, " Comfortable " - decreased from 22.2% to 17.8%, " Warm " - increased from 12.5% to 13.9%, "Hot" - increased from 4.7% to 8.6%.
The results of the study can find practical application for planning the development of the resort and tourism industry in Adjara, taking into account climate change.

Key Words: *Bioclimatic index, thermal comfort, bioclimatic stress, meteorological parameters.*

Introduction

To determine the degree of comfort or discomfort of the human environment for his health, various simple and complex thermal indices are often used.

Simple thermal indices include more than one meteorological parameter and take into account the combined effects on the human body of air temperature, humidity, wind speed, etc. Complex thermal indices are based on models of the energy budget and heat balance of the human body [1-14].

There are about 200 thermal indexes of varying complexity. Each index has its own numerical scale with the corresponding verbal description of the heat sensation of the human body, understandable to a wide range of the population (for example, "cold", "comfortable", "warm", etc.) [1-4].

The impact on the human body of the above factors can manifest itself both instantly and within hours, days, weeks, months and a longer period of time [1,5,7,15-21].

For the bioclimatic zoning of the area in order to establish its resort and tourist potential, the average monthly values of these indices are often used. One of the most popular indices is the Missenard air effective temperature (ET). This is a simple thermal indicator and is a combination of temperature, relative humidity and wind speed [22,23]. ET studies for different regions of Georgia are presented in [21,24,]. In particular, in [21] values of 8 simple thermal indices were calculated with the use of mean monthly and mean monthly for 13 hour data of meteorological elements. Between all studied simple thermal indices practically direct functional connection with the coefficient of linear correlation not lower than 0.86 is observed. The possibility of using the standard scales and categories of the indicated indices as the bioclimatic indicator in monthly time

scale is studied. As a whole, all indices adequately correspond to the degree of the bioclimatic comfort of environment for the people - with an increase in the level of comfort the mortality diminishes. Most representative for this purpose is Missenard air effective temperature in 13 hours.

This work is a continuation of previous research and presents the results of a statistical analysis of monthly average values of ET in Batumi from 1956 to 2015. The intra-annual distribution of ET values in three time periods was studied: 1956-1985, 1956-2015, 1986-2015; their repetition of occurrence by ET categories in the specified time periods was obtained, etc. The influence of climate change on ET values was revealed.

Material and methods

Data of agency on the environment of Georgia about the monthly mean max values of air temperature - T (°C), monthly mean min values air relative humidity – RH (%), and monthly mean wind speed - V (m/sec) for Batumi during the 1956-2015 were used in the work.

The analysis of data with the aid of the standard methods of mathematical statistics was conducted. All 720 cases were analyzed (months). The difference between the two means was determined using Student's t-test with a significance level $\alpha \leq 0.2$.

Information about formula for calculating the air effective temperature according to Missenard (ET), its scale and category in Table 1 is presented. °C in this Table is so-called perceptible temperature.

Table 1. Formula for calculating the air effective temperature according to Missenard, its scale and category.

Air Effective Temperature on Missenard [22,23]: $ET = 37-(37-T)/(0.68-0.0014 \cdot RH+1/(1.76+1.4 \cdot V^{0.75})) -0.29 \cdot T \cdot (1-0.01 \cdot RH)$, °C	
<1	**Very cold (ძალიან ცივა)**
1-9	**Cold (ცივა)**
9-17	**Cool (გრილა)**
17-21	**Comfortable (კომფორტი)**
21-23	**Warm (თბილა)**
23-27	**Hot (ცხელა)**
>27	**Very Hot (ძალიან ცხელა)**

Results and discussion

Results in Table 2-4 and Fig. 1-10 are presented.

In Fig. 1-3 data about changeability of mean annual values of meteorological components of air effective temperature on Missenard in Batumi in 1956-2015 are presented. As follows from these figures, trends of all three mean annual components of ET have the form of the third power polynomial.

The range of changes in the mean annual real values of these components is as follows: T - from 16.8 to 21.5 °C, mean value – 18.7 °C; RH - from 64.4 to 72.8%, mean value – 69.3%; V - from 0.8 to 2.8 m/sec, mean value – 1.8 m/sec. The range of changes in the mean annual of trends component of these meteorological parameters is as follows: T - from 18.3 to 20.4 °C, mean value – 18.7 °C; RH - from 68.0 to 71.8%, mean value – 69.3%; V -from 1.0 to 2.7 m/sec, mean value – 1.8 m/sec.

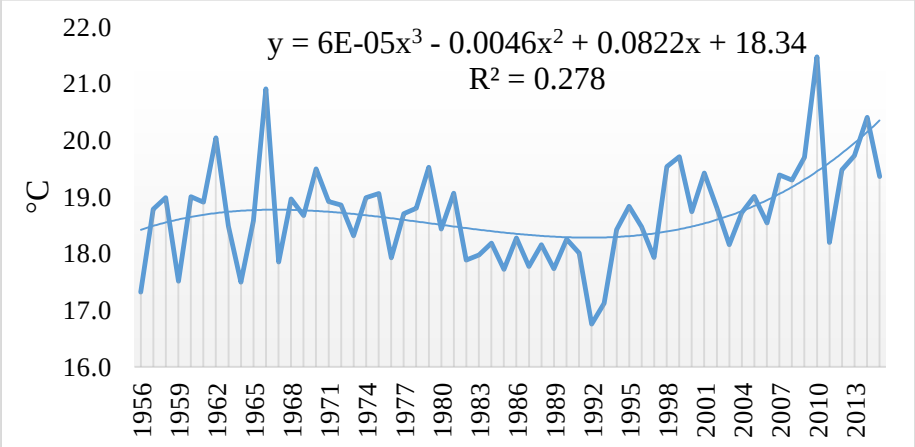


Fig.1. Trend of mean max annual values of air temperature in Batumi in 1956-2015.

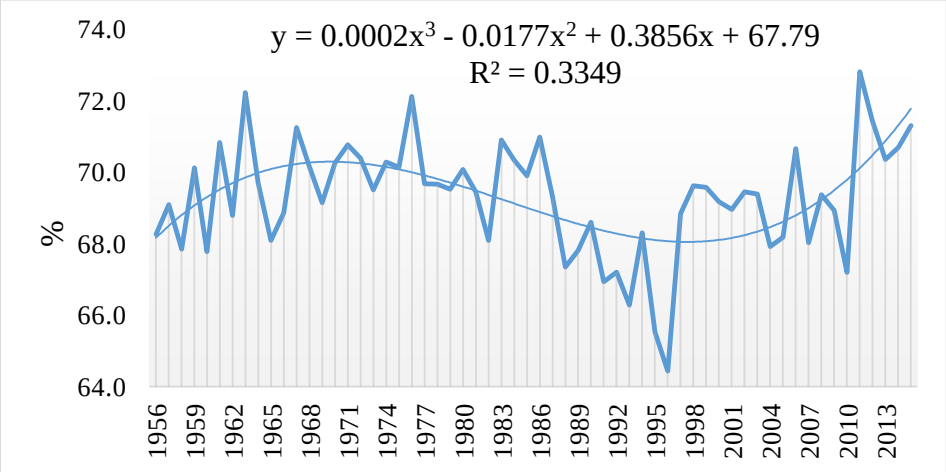


Fig. 2. Trend of mean min annual values of air relative humidity in Batumi in 1956-2015.

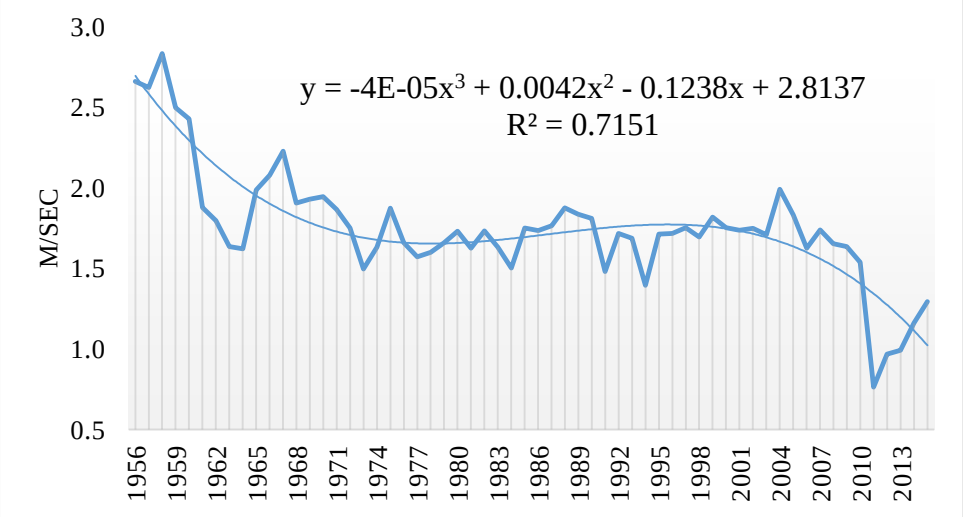


Fig. 3. Trend of mean annual values of wind speed in Batumi in 1956-2015.

Data analysis also showed that the range of changes of the mean monthly values of the indicated meteorological parameters in 1956-2015 is as follows: T - from 4.8 to 30.5 °C, RH - from 48.4 to 82.1 %, V - from 0.0 to 3.6 m/sec.

In Table 2 and 3 data about difference between mean monthly, in cold, warm periods and annual values of meteorological parameters in Batumi in 1986-2015 and 1956-1985.

Table 2. Difference between mean monthly, in cold period and annual values of meteorological parameters in Batumi in 1986-2015 and 1956-1985 (ΔT, ΔRH and ΔV).

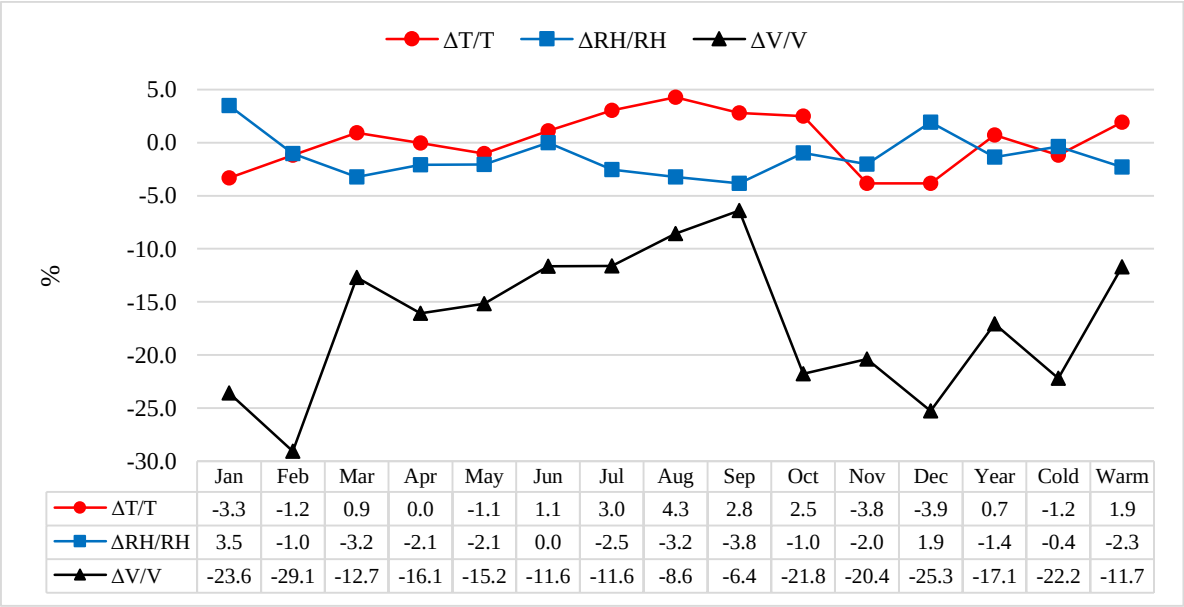
Variable	Jan	Feb	Mar	Oct	Nov	Dec	Cold	Year
ΔT	-0.4	-0.1	0.1	0.5	-0.6	-0.5	-0.2	0.1
α(ΔT)	no sign	no sign	no sign	0.2	0.2	no sign	no sign	no sign
ΔRH	2.3	-0.7	-2.2	-0.7	-1.4	1.2	-0.2	-1.0
α(ΔRH)	0.1	no sign	0.12	no sign	no sign	no sign	no sign	0.01
ΔV	-0.5	-0.6	-0.2	-0.3	-0.3	-0.4	-0.4	-0.3
α(ΔV)	<0.01	<0.01	0.05	<0.01	<0.01	<0.01	<0.01	<0.01

Table 3. Difference between mean monthly and in warm period values of meteorological parameters in Batumi in 1986-2015 and 1956-1985 (ΔT, ΔRH and ΔV).

Variable	Apr	May	Jun	Jul	Aug	Sep	Warm
ΔT	0.0	-0.2	0.3	0.8	1.1	0.7	0.4
α(ΔT)	no sign	no sign	no sign	<0.01	<0.01	0.05	<0.01
ΔRH	-1.4	-1.5	0.0	-1.9	-2.4	-2.8	-1.7
α(ΔRH)	0.2	0.12	no sign	0.04	<0.01	<0.01	<0.01
ΔV	-0.3	-0.3	-0.2	-0.2	-0.1	-0.1	-0.2
α(ΔV)	<0.01	0.03	0.05	0.06	0.15	0.20	0.04

As follows from these tables, the variability of the meteorological parameters, determining the value of ET, in 1986-2015 compared to 1956-1985 is as follows.

- ΔT - growth in October, from July to September and in the warm half of the year; decrease - only in November.
- ΔRH - decrease in March, April, May from July to September, in the warm half of the year and in general for the year; growth in January only.
- ΔV - decrease in all months and seasons of the year.

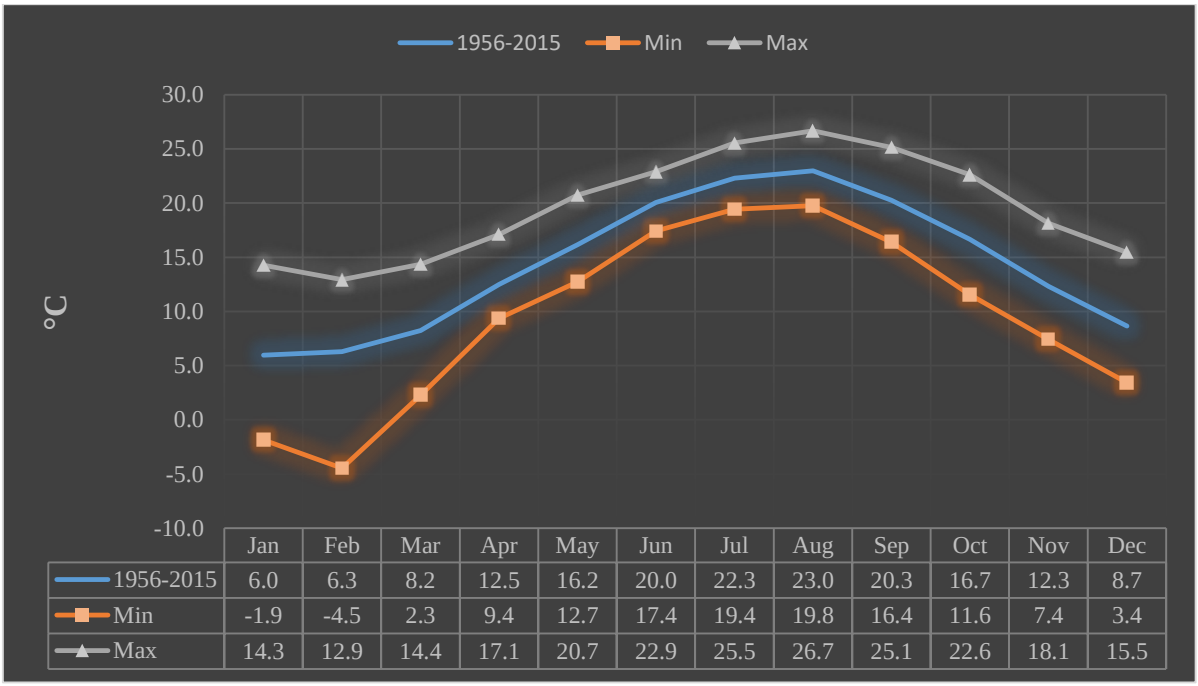


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Cold	Warm
ΔT/T	-3.3	-1.2	0.9	0.0	-1.1	1.1	3.0	4.3	2.8	2.5	-3.8	-3.9	0.7	-1.2	1.9
ΔRH/RH	3.5	-1.0	-3.2	-2.1	-2.1	0.0	-2.5	-3.2	-3.8	-1.0	-2.0	1.9	-1.4	-0.4	-2.3
ΔV/V	-23.6	-29.1	-12.7	-16.1	-15.2	-11.6	-11.6	-8.6	-6.4	-21.8	-20.4	-25.3	-17.1	-22.2	-11.7

Fig. 4. Intra-annual distribution relative differences of mean monthly values of T, RH and V in Batumi in 1956-1985 and 1986-2015. ΔT/T=100·[T(2015-1986)-T(1956-1985)]/T(1956-2015), % etc.

In fig. 4, for clarity, data on the relative difference of the indicated meteorological parameters in different months and seasons of the year are presented. As follows from this figure, the variability of ΔV/V (decreasing) is much more significant than ΔT/T and ΔRH/RH changeability.

Results of analysis of data on ET values (Fig. 5) and its variability (Fig. 6-9, Table 4) in Batumi in 1956-2015 are presented below.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1956-2015	6.0	6.3	8.2	12.5	16.2	20.0	22.3	23.0	20.3	16.7	12.3	8.7
Min	-1.9	-4.5	2.3	9.4	12.7	17.4	19.4	19.8	16.4	11.6	7.4	3.4
Max	14.3	12.9	14.4	17.1	20.7	22.9	25.5	26.7	25.1	22.6	18.1	15.5

Fig. 5. Intra-annual distribution of Min, Max and mean monthly values of ET in Batumi in 1956-2015.

As follows from Fig. 5 monthly values of ET vary from -4.5 °C (February, category “Very cold”) to 26.7 °C (August, category ”Hot”). The mean monthly values of ET from 1956 to 2015 vary from 6.0 °C (January, category “Cold”) to 23.0 °C (August, category ”Hot”).

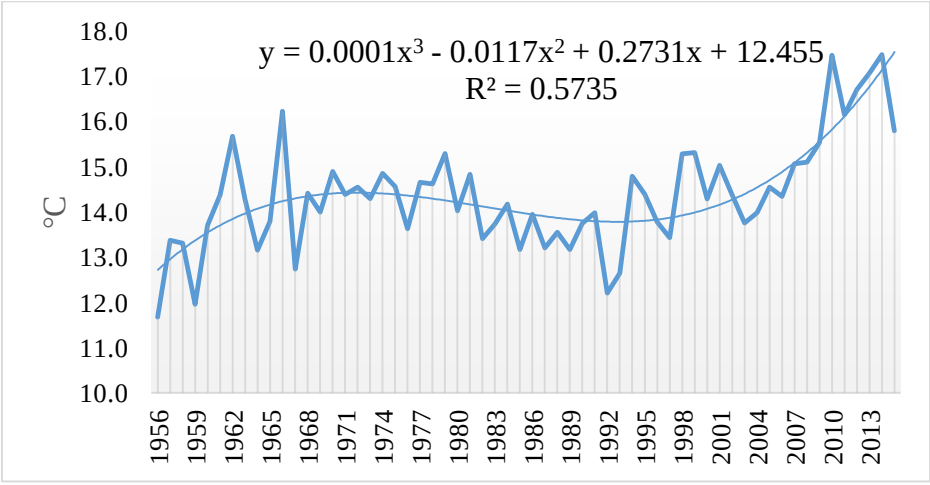
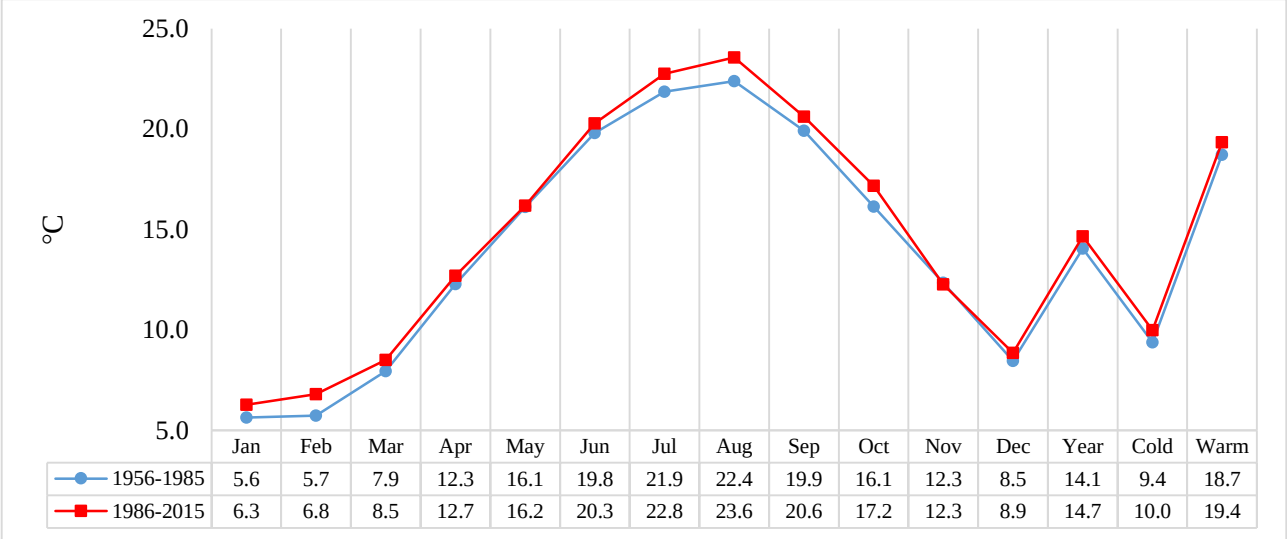


Fig. 7. Trend of mean annual values of air effective temperature on Missenard in Batumi in 1956-2015.

Trend of mean annual values of air effective temperature on Missenard in Batumi in 1956-2015 as T, RH and V, have the form of the third power polynomial (Fig. 7). The range of changes in the mean annual

real values of ET is 11.7 °C (category “Cool”) ÷ 17.5 °C (category “Comfortable”); the range of changes in the mean annual of trends component of ET is 12.7 °C (category “Cool”) ÷ 17.5 °C (category “Comfortable”).

Data on intra-annual distribution of mean monthly and seasonal values of ET in Batumi in 1956-1985 and 1986-2015 in Fig. 7 are presented. In Fig. 8 difference between mean monthly and seasonal values of ET in Batumi in 1986-2015 and 1956-1985 are presented.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Cold	Warm
1956-1985	5.6	5.7	7.9	12.3	16.1	19.8	21.9	22.4	19.9	16.1	12.3	8.5	14.1	9.4	18.7
1986-2015	6.3	6.8	8.5	12.7	16.2	20.3	22.8	23.6	20.6	17.2	12.3	8.9	14.7	10.0	19.4

Fig. 7. Intra-annual distribution of mean monthly and seasonal values of ET in Batumi in 1956-1985 and 1986-2015.

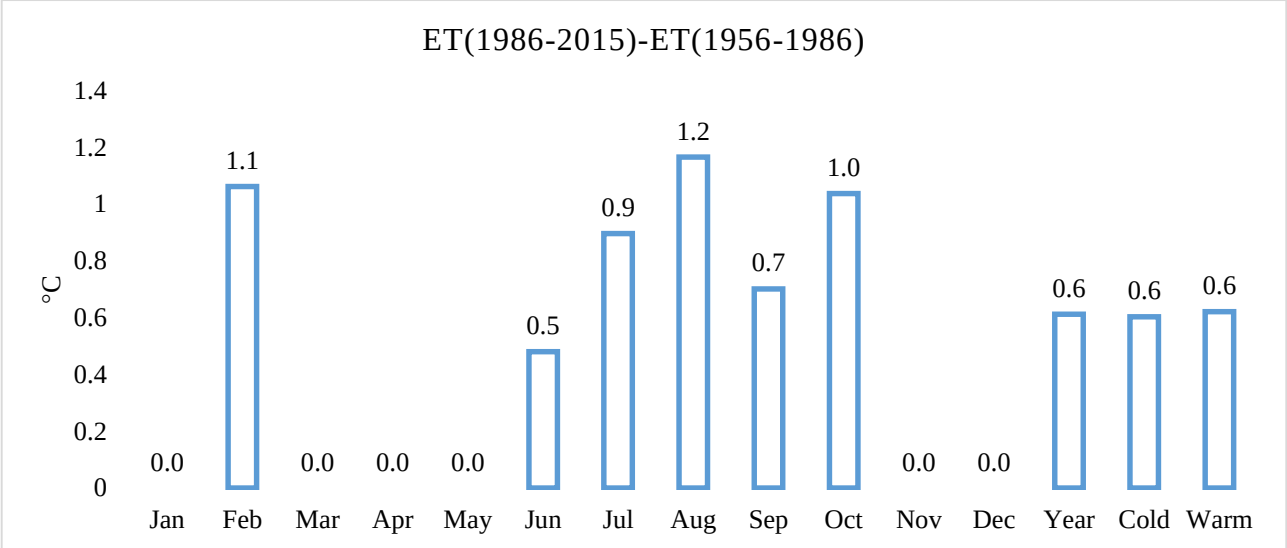


Fig. 8. Difference between mean monthly and seasonal values of ET in Batumi in 1986-2015 and 1956-1985 (0.0 – insignificant difference).

As follows from Fig. 7 and 8 in general, in 1986–2015, compared with 1956–1986, there was an increase of ET values for all months and seasons of the year. At the same time, a significant increase of ET values was noted in February, from June to October, in the cold and warm half-years, and in the whole year.

In Fig. 9 data about repetition of monthly values of ET in Batumi in 1986-2015 and 1956-1985 on its categories are presented.

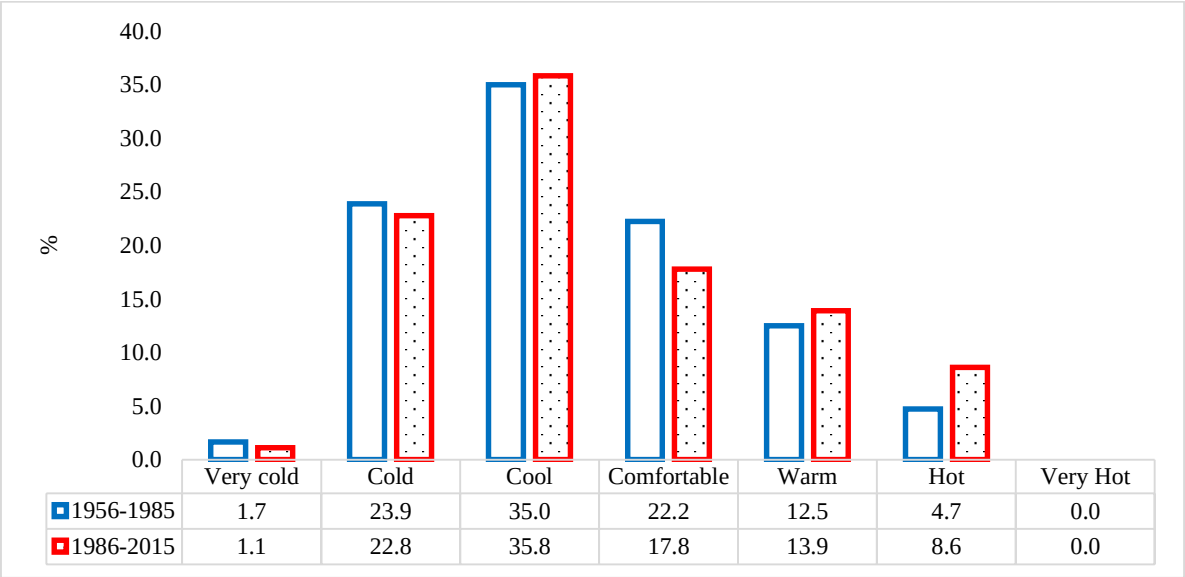


Fig. 9. Repetition of monthly values of ET in Batumi in 1986-2015 and 1956-1985.

As follows from Fig. 9 in 1986-2015, compared with 1956-1985, repetition of ET values for the category “Very cold” decreased from 1.7% to 1.1%, “Cold” - decreased from 23.9% to 22.8%, “Cool” - increased from 35.0% to 35.8%, "Comfortable" - decreased from 22.2% to 17.8% (reduction by 1.25 times), "Warm" - increased from 12.5% to 13.9%, “Hot" - increased from 4.7% to 8.6%. For categories "Warm" ÷ “Hot" repetition of ET values increase from 17.2% до 22.5 % (growth by 1.3 times). Thus, the increase of repetition of ET values for the "Warm" ÷ “Hot" categories mainly occurred due to a decrease of repetition of ET values for the "Comfortable" category. In accordance with Fig. 2 of [21], such a shift in the repetition of ET values towards warming should be favorable for human health (in terms of cardiovascular diseases). However, this statement requires further research, since the work [21] was carried out for Tbilisi conditions

Finally, Table 4 provides information on categories of mean monthly and seasonal values of ET in Batumi in 1986-2015 and 1956-1985.

Table 4. Category of mean monthly and seasonal values of ET in Batumi in 1986-2015 and 1956-1985.

Year/ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	**Aug**	Sep	**Oct**	Nov	Dec	Year	Cold	Warm
1956-1985	Cold	Cold	Cold	Cool	Cool	Comf.	Warm	**Warm**	Comf.	**Cool**	Cool	Cold	Cool	Cool	Comf.
1986-2015	Cold	Cold	Cold	Cool	Cool	Comf.	Warm	**Hot**	Comf.	**Comf.**	Cool	Cold	Cool	Cool	Comf.

As follows from this Table, in the second period of time, compared with the first, the change in the categories of ET values occurred only in August (“Warm” → “Hot”) and October (“Cool” → "Comfortable").

Conclusion

In the future, we will continue such studies. Particular attention will be paid to predicting the variability of various bioclimatic indicators for several decades to come. The results of these studies can find practical application for planning the development of the resort and tourism industry both in Adjara and in other regions of Georgia, taking into account climate change.

Note

This work was presented as a report at the International Scientific Conference Black Sea Region at the Crossroads of Civilizations "BSRCC", 5-6 July, 2022, Batumi, Georgia. https://bsu.edu.ge/main/page/16543/index.html

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მისენარდის მიხედვით ჰაერის საშუალო თვიური ეფექტური ტემპერატურის ცვალებადობა ბათუმში 1956-2015 წწ.

ა. ამირანაშვილი, ნ. ჯაფარიძე, ლ. ქართველიშვილი,
კ. ხაზარაძე, ა. რევიშვილი

რეზიუმე

წარმოდგენილია ბათუმში 1956 - 2015 წლებში მისენარდის მიხედვით ჰაერის ეფექტური ტემპერატურის საშუალო თვიური მნიშვნელობების (ET) სტატისტიკური ანალიზის შედეგები. შესწავლილი იქნა ET-ს მნიშვნელობების შიდაწლიური განაწილება დროის სამ პერიოდში: 1956-1985, 1956-2015, 1986-2015 წწ.; მიღებულ იქნა მათი განმეორადობა ET-ს კატეგორიების მიხედვით

მითითებულ დროში და სხვ. გამოვლინდა კლიმატის ცვლილების გავლენა ET-ს მნიშვნელობებზე.

კერძოდ, ნაჩვენებია, რომ 1986-2015 წწ. 1956-1985 წლებთან შედარებით ET-ს მნიშვნელობების განმეორადობა "Very cold" კატეგორიისთვის შემცირდა 1.7%-დან 1.1%-მდე, "Cold" - შემცირდა 23.9%-დან 22.8%-მდე, "Cool" - გაიზარდა 35.0%-დან 35.8%-მდე, "Comfortable " - შემცირდა 22.2%-დან 17.8%-მდე, „Warm“ - გაიზარდა 12.5%-დან 13.9%-მდე, „Hot“ - გაიზარდა 4.7%-დან 8.6%-მდე. კვლევის შედეგებს შეუძლია ჰქონდეს პრაქტიკული გამოყენება აჭარაში საკურორტო და ტურისტული ინდუსტრიის განვითარების დაგეგმვისთვის, კლიმატის ცვლილების გათვალისწინებით.

საკვანძო სიტყვები: ბიოკლიმატური ინდექსი, თერმული კომფორტი, ბიოკლიმატური სტრესი, მეტეოროლოგიური პარამეტრები.

Изменчивость среднемесячных значений эффективной температуры воздуха по Миссенарду в Батуми в 1956-2015 гг.

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Резюме

Представлены результаты статистического анализа среднемесячных значений эффективной температуры воздуха по Миссенарду (ET) в Батуми с 1956 по 2015 гг. Изучено внутригодовое распределение значений ET в три периода времени: 1956-1985, 1956-2015, 1986-2015 гг.; получена их повторяемость по категориям ET в указанные периоды времени и др. Выявлено влияние изменения климата на значения ET.

В частности, показано, что в 1986-2015 гг. во сравнению с 1956-1985 гг. повторяемость значений ET для категории “ Very cold” уменьшилась с 1.7% до 1.1%, “Cold” - уменьшилась с 23.9% до 22.8%, “Cool” - увеличилась с 35.0% до 35.8%,, “Comfortable” - уменьшилась с 22.2 % до 17.8%, “Warm” - увеличилась с 12.5% до 13.9%, “Hot” - увеличилась с 4.7% до 8.6%.

Результаты исследования могут найти практическое применение для планирования развития курортно-туристической индустрии в Аджарии с учетом изменения климата.

Ключевые слова: биоклиматический индекс, тепловой комфорт, биоклиматический стресс, метеорологические параметры.