მიხეილ ნოდიას სახ. გეოფიზიკის ინსტიტუტის შრომები, ISSN 1512-1135, ტ. LXXII, 2020
Transactions of Mikheil Nodia Institute of Geophysics, ISSN 1512-1135, vol. LXXII, 2020
Труды Института геофизики им. Михаила Нодиа, ISSN 1512-1135, т. LXXII, 2020

CHANGEABILITY OF THE HOLIDAY CLIMATE INDEX (HCI) IN TBILISI

[1]Amiranashvili A., [2]Kartvelishvili L., [3]Matzarakis A.

[1]Mikheil Nodia Institute of Geophysics of Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia
[2]National Environmental Agency of Georgia, Tbilisi, Georgia
[3]University of Freiburg, Meteorological Institute, Germany
avtandilamiranashvili@gmail.com

Introduction

Weather and climate are two factors that in many respects influence on tourism development. Many climate indices for tourism have been applied in past research [1]. The most widely known and applied index is the Tourism Climate Index (TCI) proposed by Mieczkowski [2]. In south Caucasus countries, monthly value of TCI be calculated in Georgia, first for Tbilisi [3], then for many other locations of Caucasus (Armenia, Azerbaijan, North Caucasus etc.) [4-11].

Despite the TCI's wide application, it has been subject to substantial critiques [12]. The four key deficiencies of the TCI include: (1) the subjective rating and weighting system of climatic variables; (2) it neglects the possibility of an overriding influence of physical climatic parameters (e.g., rain, wind); (3) the low temporal resolution of climate data (i.e., monthly data) has limited relevance for tourist decision-making; and (4) it neglects the varying climatic requirements of major tourism segments and destination types (i.e., beach, urban, winter sports tourism).

To overcome the above noted limitations of the TCI, a Holiday Climate Index (HCI) was developed to more accurately assess the climatic suitability of destinations for tourism. The word 'holiday' was chosen to better reflect what the index was designed for (*i.e.*, leisure tourism), since tourism is much broader by definition ("Tourism is a social, cultural and economic phenomenon which entails the movement of people to countries or places outside their usual environment for personal or business/professional purposes" [12-16].

Results of comparison of the holiday climate index and the tourism climate index in Tbilisi are presented in [17]. Comparison of the values and categories of the Tourism Climate Index and Holiday Climate Index in Tbilisi shows that the intra-annual variation of both indices is similar and has a bimodal form. However, given that the TCI is calculated for the so-called "average tourist" (regardless of gender, age, physical condition), the value and category of this index is lower than the HCI values and categories. In general, HCI more adequately determines the bioclimatic state of the environment for the development of various types of tourism than TCI [17].

This paper provides more detailed information on the variability of the monthly values of the HCI in Tbilisi in 1956-2015 than in the previous study [17]. It also presents data on the interval forecast of variability of HCI in Tbilisi for the next few decades.

Material and methods

The HCI uses five climatic variables related to the three facets essential to tourism (table 1): thermal comfort (TC), aesthetic (A), and physical (P) facet. The five climatic variables used for the HCI input are maximum air temperature and relative humidity (TC), cloud cover (A), precipitation and wind (P) [12]. The HCI score is calculated according to the following formula: $\mathbf{HCI = 4 \cdot T + 2 \cdot A + 3 \cdot R_d + 1 \cdot W.}$ In tables 1-3 components of Holiday Climate Index, HCI's rating scheme and HCI's category are presented.

Table 1. Components of Holiday Climate Index (HCI)

Facet	Climatic Variable	Index Weighting (%)
Thermal Comfort (TC)	Dry-bulb Temperature (°C): Maximum Temperature (°C)	40%
	Relative Humidity (%): Mean RH	
Aesthetic (A)	Cloud Cover (%)	20%
Physical (P)	Amount of Rain (mm)	30%
	Wind Speed (km/h)	10%

Table 2. HCI's Rating Scheme

Rating	T - Effective Temperature (°C) [2]	A - Daily Cloud Cover (%)	R_d - Daily Precipitation (mm)	W - Wind Speed (km/h)
10	23÷25	11÷20	0	1÷9
9	20÷22; 26	1÷10; 21÷30	<3	10÷19
8	27÷28	0; 31÷40	3÷5.99	0; 20÷29
7	18÷19; 29÷30	41÷50		
6	15÷17; 31÷32	51÷60		30÷39
5	11÷14; 33÷34	61÷70	6÷8.99	
4	7÷10; 35÷36	71÷80		
3	0÷6	81÷90		40÷49
2	-5÷-1; 37÷39	90÷99	9÷12	
1	<-5	100		
0	>39		>12	50÷70
-1			>25	
-10				>70

Table 3. HCI's Category

HCI Score	Category	HCI Score	Category
90÷100	Ideal	40÷49	Marginal
80÷89	Excellent	30÷39	Unfavorable
70÷79	Very Good	20÷29	Very Unfavorable
60÷69	Good	10÷19	Extremely Unfavorable
50÷59	Acceptable	9÷-9; -10÷-20	Impossible

For the monthly mean values of HCI calculation data of National Environmental Agency of Georgia from 1956 to 2015 were used.

In the work analysis of data is carried out with the use of the standard statistical analysis methods. The following designations will be used below: Mean – average values; Min – minimal values; Max - maximal values; Range - variational scope; St Dev - standard deviation; σ_m – standard error; Cv, % – coefficient of variation (Cv = 100·St Dev/Average); 95%(+/-) - 95% confidence interval of mean; I)1956÷1985 – mean value of HCI in 1956-1985, first period; II)1986÷2015 - second period; t - Student criterion; Diff.(II-I) – difference between mean values of HCI in second and first periods were determined with use of Student criterion; R - coefficient of linear correlation; α - the level of significance; Δ□ = 100· Diff.(II-I)/Mean(1956-2015) - relative variability of the difference between the mean values of the HCI in two periods of time relative to the mean value for the entire observation period, %; Δ□ = 100·[HCI(2015) – HCI(1956)]/

Mean(1956-2015) - relative variability of the difference between the HCI values in 2015 and 1956, determined by linear regression equations, in relation to the mean value for the entire observation period, %; a and b - coefficients of the linear equation of the trend of HCI values (HCI = a·year/month + b).

Interval prediction of the variability of the HCI values for the coming decades was carried out using the "MULTIPLE SEASONAL MODEL" (program "MESOSAUR" [18]); 95%_Low_Pred and 95%_Upp_Pred - 95% of the lower and upper levels of the confidence interval of the prediction values of HCI, respectively.

Results and discussion

The results in fig. 1-6 and tables 4-6 are presented. Fig. 1,2 and tables 4 and 5 present data on the statistical characteristics and changeability of monthly and seasonal values of HCI in Tbilisi in 1956-2015.

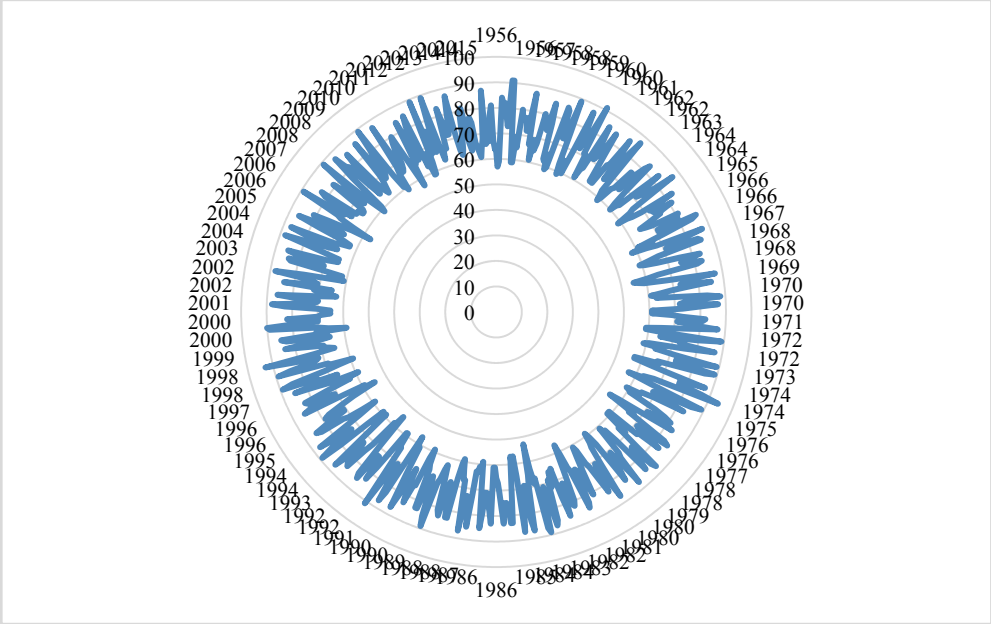


Fig. 1. Monthly values of HCI in Tbilisi in 1956-2015.

Table 4. Statistical characteristics of HCI in Tbilisi during the cold season (1956-2015)

Parameter	Jan	Feb	Mar	Oct	Nov	Dec	Cold	Year
Mean	62.0	62.5	66.7	82.8	68.6	64.0	67.8	72.5
Min	55.0	53.0	59.0	67.0	59.0	55.0	63.0	69.8
Max	67.0	72.0	77.0	94.0	80.0	71.0	72.3	75.8
Range	12.0	19.0	18.0	27.0	21.0	16.0	9.3	6.1
St Dev	3.4	4.3	4.0	6.1	4.0	3.5	2.2	1.3
σm	0.44	0.56	0.52	0.79	0.52	0.45	0.28	0.17
Cv (%)	5.5	6.8	6.0	7.3	5.8	5.4	3.2	1.8
95%(+/-)	0.9	1.1	1.0	1.6	1.0	0.9	0.5	0.3
II)1986÷2015	62.6	63.3	68.0	83.5	68.8	64.2	68.4	72.6
I)1956÷1985	61.3	61.7	65.3	82.0	68.4	63.8	67.1	72.4
Diff.(II-I)	1.2	1.6	2.6	1.5	0.4	0.4	1.3	0.1
t	1.41	1.43	2.70	0.95	0.39	0.44	2.41	0.36
α(t)	0.15	0.15	0.01	no	no	no	0.02	no
R	0.19	0.10	0.37	0.09	0.11	0.15	0.31	0.02
Δ□, %	1.9	2.6	3.9	1.8	0.6	0.6	1.9	0.1
α(R)	0.15	no	<0.01	no	no	no	0.01	no
a	0.0364	0.0241	0.0851	0.0297	0.0253	0.0302	0.0385	-0.0017
b	-10.38	14.58	-102.22	23.81	18.32	4.09	-8.63	75.93
Δ□, %	3.5	2.3	7.5	2.1	2.2	2.8	3.4	-0.1

Table 5. Statistical characteristics of HCI in Tbilisi during the warm season (1956-2015).

Parameter	Apr	May	Jun	Jul	Aug	Sep	Warm	Year
Mean	76.8	83.8	76.5	71.8	72.6	82.0	77.2	72.5
Min	65.0	67.0	65.0	67.0	64.0	74.0	72.2	69.8
Max	89.0	90.0	85.0	77.0	79.0	91.0	81.5	75.8
Range	24.0	23.0	20.0	10.0	15.0	17.0	9.3	6.1
St Dev	7.31	3.97	4.49	2.83	3.41	3.64	2.03	1.31
σm	0.95	0.52	0.58	0.37	0.44	0.47	0.26	0.17
Cv (%)	9.5	4.7	5.9	3.9	4.7	4.4	2.6	1.8
95%(+/-)	1.9	1.0	1.1	0.7	0.9	0.9	0.5	0.3
II)1986÷2015	77.5	84.0	75.8	70.8	71.2	80.9	76.7	72.6
I)1956÷1985	76.0	83.6	77.1	72.8	74.0	83.1	77.8	72.4
Diff.(II-I)	1.4	0.5	-1.3	-1.9	-2.8	-2.2	-1.0	0.1
t	0.76	0.45	1.13	2.79	3.42	2.39	2.04	0.36
α(t)	no	no	no	<0.01	<0.01	0.02	0.05	no
Δ□, %	1.8	0.6	-1.7	-2.6	-3.9	-2.7	-1.3	0.1
R	0.030	0.09	0.17	0.42	0.47	0.38	0.36	0.02
α(R)	no	no	no	<0.01	<0.01	<0.01	<0.01	no
a	51.32	3.09	165.25	207.95	256.02	239.3	160.49	75.93
b	1.0	1.4	-3.4	-5.6	-7.5	-5.7	-3.2	-0.1
Δ□, %	1.8	0.6	-1.7	-2.6	-3.9	-2.7	-1.3	0.1

In the period from 1956 to 2015 (fig. 1, tables 4, 5) monthly HCI values varied from 53.0 ("Acceptable", February) to 94 ("Ideal", October). The mean monthly HCI values for the entire observation period varied from 62.0 ("Good", January) to 83.8 ("Excellent", May). Maximal value of Range for monthly values of HCI is 27.0 (October), Minimal - 10.0 (July).

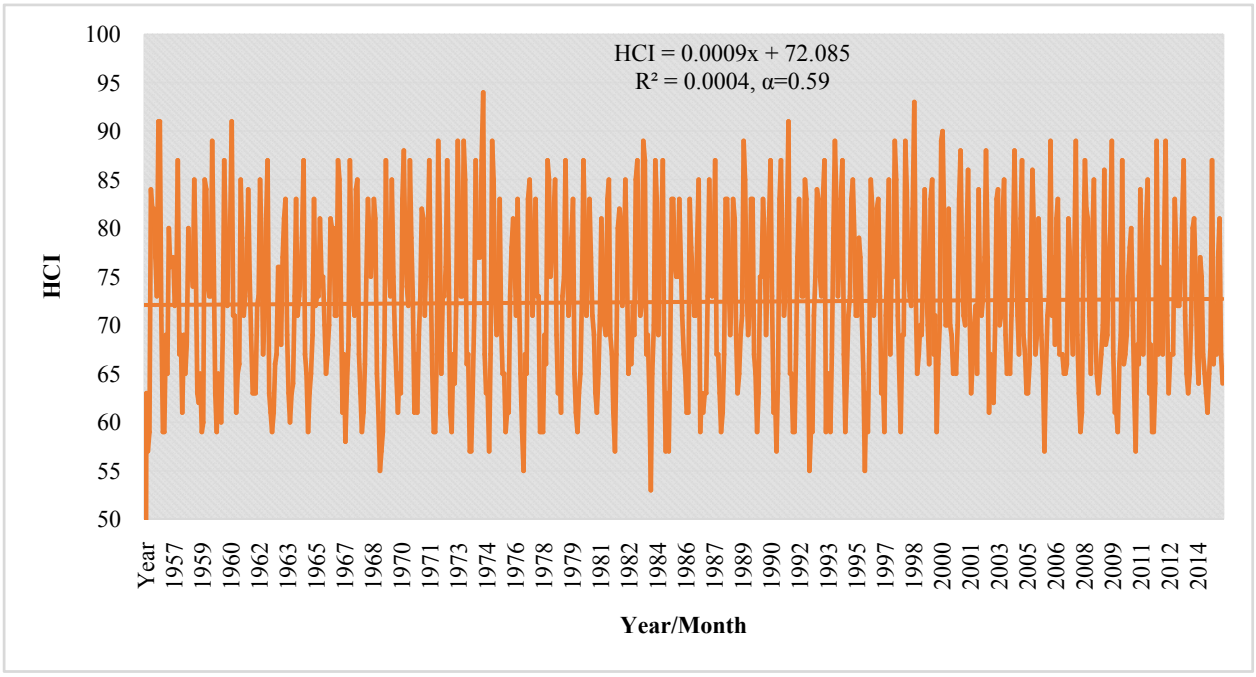
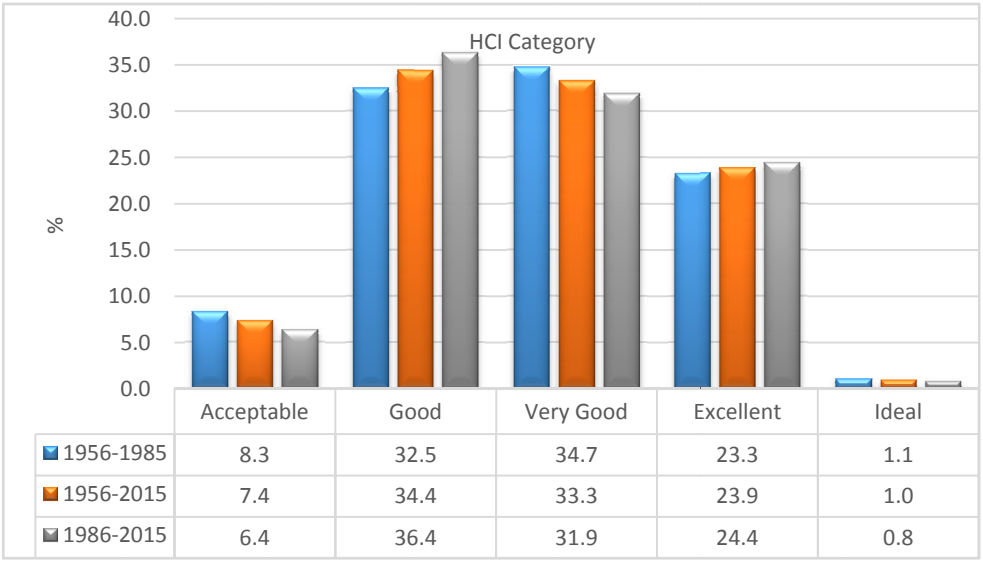


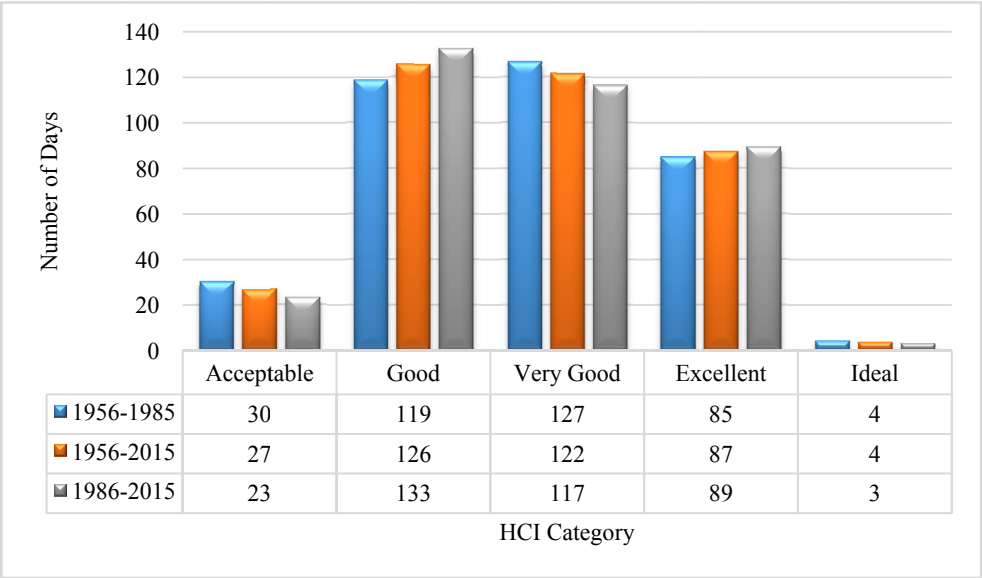
Fig. 2. Trend of monthly values of HCI in Tbilisi in 1956-2015.

The trend of monthly HCI values for all observational data is generally insignificant positive (fig. 2). A significant linear positive trend in HCI values in certain months of the year was observed in January, March, the cold half of the year; negative - from July to September and in the warm half of the year. A significant increase in average monthly and seasonal HCI values in the second period of time compared to the first was observed from January to March and in the cold half of the year, a decrease - from July to September and in the warm half of the year. The maximum absolute value Δ□ = 3.9% (March, August) and Δ□ = 7.5% (March). The values of the coefficient of variation vary from 3.9% (July) to 9.5% (March). Thus, the variability of the HCI values in Tbilisi during the study period is generally insignificant (tables 4, 5).



	Acceptable	Good	Very Good	Excellent	Ideal
1956-1985	8.3	32.5	34.7	23.3	1.1
1956-2015	7.4	34.4	33.3	23.9	1.0
1986-2015	6.4	36.4	31.9	24.4	0.8

Fig. 3. Repetition of category of monthly values of HCI in Tbilisi in three periods of time.



	Acceptable	Good	Very Good	Excellent	Ideal
1956-1985	30	119	127	85	4
1956-2015	27	126	122	87	4
1986-2015	23	133	117	89	3

Fig. 4. Number of days with different category of HCI in Tbilisi in three periods of time.

In the period from 1956 to 2015 the highest repeatability of HCI values (fig. 3.4) was in the "Good" category (34.4% of cases, 126 days per year), the lowest - in the "Ideal" category (1.0% of cases, 4 days per year). In the second period compared to the first in Tbilisi, climate change did not lead to a change in HCI categories. At the same time, the frequency of occurrence of the HCI "Acceptable" category decreased from

8.3% to 6.4% (respectively, 30 and 23 days a year), the "Good" category increased - from 32.5% to 36.4% (respectively, 119 and 133 days a year), the "Very Good" category decreased from 34.7% to 31.9% (127 and 117 days a year, respectively), the "Excellent" category increased from 23.3% to 24.4% of cases (respectively 85 and 89 days a year), the "Ideal" category decreased from 1.0% to 0.8% (4 and 3 days a year, respectively). In general, in Tbilisi practically all year round there are favorable bioclimatic conditions for recreation and tourism.

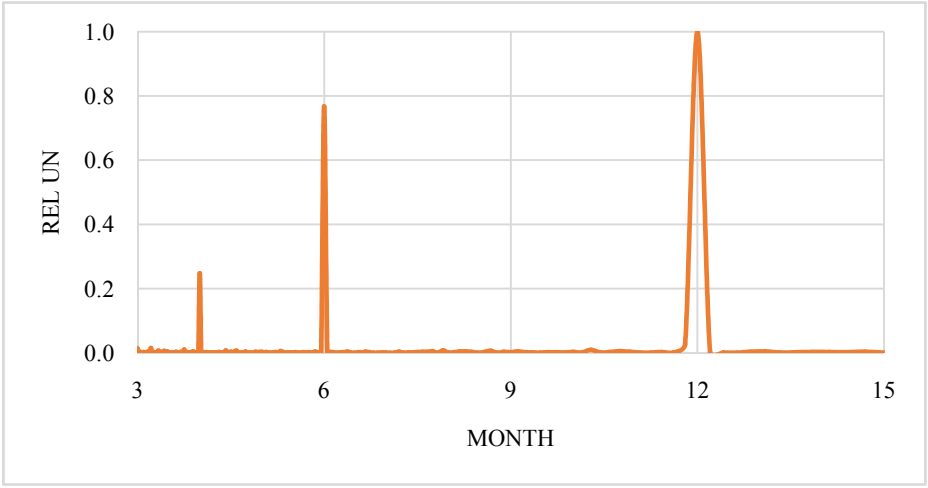
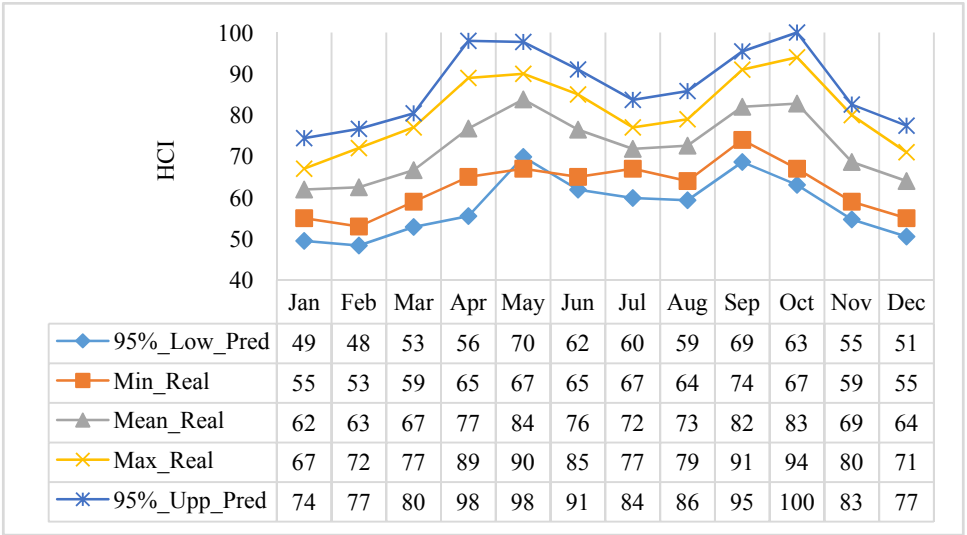


Fig. 5. Periodicity of values of HCI in Tbilisi.

The intra-annual distribution of mean monthly HCI values has a bimodal form ([17], tables 4, 5). Analysis with use [18] of the entire series of monthly HCI values from 1956 to 2015 confirmed that the first and second extremes of HCI periodicity occur at 12 and 6 months, respectively (fig. 5). Note that in the time series of observations there is also a third small extremum of the periodicity - 4 months.

Considering that the variability of the values of the Holiday Climate Index in Tbilisi is not very significant, the interval prediction of the variability of the HCI values for the coming decades was carried out using the "MULTIPLE SEASONAL MODEL" (program "MESOSAUR" [18]) taking into account two values of periodicity (12 and 6 months). The calculation results are shown in fig. 6 and table 6.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
95%_Low_Pred	49	48	53	56	70	62	60	59	69	63	55	51
Min_Real	55	53	59	65	67	65	67	64	74	67	59	55
Mean_Real	62	63	67	77	84	76	72	73	82	83	69	64
Max_Real	67	72	77	89	90	85	77	79	91	94	80	71
95%_Upp_Pred	74	77	80	98	98	91	84	86	95	100	83	77

Fig. 6. Interval forecast of HCI values for the next few decades compared with Min_Real, Mean_Real and Max_Real HCI values in 1956-2015.

As follows from fig. 6 the predicted maximum monthly HCI values (95%_Upp_Pred) are higher than the maximum monthly real HCI values (95%_Max_Real). The predicted minimum monthly values of

HCI (95%_Low_Pred) excluding May are lows than the real minimum monthly values of HCI (95%_Min_Real).

Thus, in the forecast period, the range of variability of mean monthly HCI values is expected to expand as compared to 1956-2015.

Finaly, information on the expansion of the range of variability of the categories of mean monthly HCI values in the prognostic period compared to 1956-2015 in table 6 is presented.

Table 6. Interval forecast of HCI categories for the next few decades compared with Min_Real, Mean_Real and Max_Real HCI categories in 1956-2015.

Parameter	95%_Low_Pred	Min_Real	Mean_Real	Max_Real	95%_Upp_Pred
Jan	***Marginal***	***Acceptable***	Good	***Good***	***Very Good***
Feb	***Marginal***	***Acceptable***	Good	Very Good	Very Good
Mar	Acceptable	Acceptable	Good	***Very Good***	***Excellent***
Apr	***Acceptable***	***Good***	Very Good	***Excellent***	***Ideal***
May	***Very Good***	***Good***	Excellent	Ideal	Ideal
Jun	Good	Good	Very Good	***Excellent***	***Ideal***
Jul	Good	Good	Very Good	***Very Good***	***Excellent***
Aug	***Acceptable***	***Good***	Very Good	***Very Good***	***Excellent***
Sep	***Good***	***Very Good***	Excellent	Ideal	Ideal
Oct	Good	Good	Excellent	Ideal	Ideal
Nov	Acceptable	Acceptable	Good	Excellent	Excellent
Dec	Acceptable	Acceptable	Good	Very Good	Very Good

As follows from Table 6, in the next few decades, the maximum categories of real HCI values may increase by one gradation in the following months: January: Good→ Very Good; March, July and August: Very Good → Excellent; April and June: Excellent → Ideal. The minimum real HCI categories may decline by one gradation in the following months: January and February: Acceptable → Marginal; April and August: Good →Acceptable; September: Very Good → Good. Minimum HCI value category is expected to increase by one gradation in May: Good → Very Good.

Thus, favorable bioclimatic conditions for recreation and tourism will remain practically all year round in Tbilisi and in the next few decades.

Conclusion

In the future, we plan to continue similar studies for other regions of Georgia (mapping the territory of Georgia by HCI values, studying their long-term trends, statistical forecasting of HCI variability due to climate change). Research will also continue on the impact of various simple and complex bioclimatic indices, including HCI, on the health of the peoples.

ლიტერატურა - REFERENCES - ЛИТЕРАТУРА

1. Matzarakis A. Weather - and Climate-Related Information for Tourism. Tourism and Hospitality Planning & Development, August, 2006, vol. 3, No. 2, pp. 99–115.
2. Mieczkowski Z. The Tourism Climate Index: A Method for Evaluating World Climates for Tourism. The Canadian Geographer 1985, N 29, pp. 220-233.
3. Amiranashvili A., Matzarakis A., Kartvelishvili L. Tourism Climate Index in Tbilisi. Trans. of the Institute of Hydrometeorology, ISSN 1512-0902, Tbilisi, 18 – 19 November, 2008, vol. 115, pp. 27 - 30.
4. Amiranashvili, A., Chargazia, Kh., Matzarakis, A. Comparative Characteristics of the Tourism Climate Index in the South Caucasus Countries Capitals (Baku, Tbilisi, Yerevan). Journal of the Georgian Geophysical Society, ISSN: 1512-1127, Issue (B). Physics of Atmosphere, Ocean, and Space Plasma, 2014, vol.17B, pp. 14-25.

5. Amiranashvili A., Chargazia Kh., Matzarakis A., Kartvelishvili L. Tourism Climate Index in the Coastal and Mountain Locality of Adjara, Georgia. International Scientific Conference "Sustainable Mountain Regions: Make Them Work". Proceedings, Borovets, Bulgaria, ISBN 978-954-411-220-2, 14-16 May,2015, pp.238-244, http://geography.bg/MountainRegions_Sofia2015
6. Rybak O. O., Rybak E. A. Application of Climatic Indices for Evaluation of Regional Differences in Tourist Attractiveness. Nauchnyy zhurnal KubGAU, №121(07), 2016, 24 p., http://ej.kubagro.ru/2016/07/pdf/16.pdf
7. Amiranashvili A.G., Japaridze N.D., Kartvelishvili L.G., Khazaradze K.R., Matzarakis A., Povolotskaya N.P., Senik I.A. Tourism Climate Index of in the Some Regions of Georgia and North Caucasus. Journal of the Georgian Geophysical Society, ISSN: 1512-1127, Issue (B). Physics of Atmosphere, Ocean, and Space Plasma, 2017, vol.20B, pp. 43-64.
8. Amiranashvili A.G., Japaridze N.D., Kartvelishvili L.G., Khazaradze K.R., Kurdashvili L.R. Tourism Climate Index in Kutaisi (Georgia). International Scientific Conference „Modern Problems of Ecology", Proceedings, ISSN 1512-1976, v. 6, Kutaisi, Georgia, 21-22 September, 2018, pp. 227-230.
9. Amiranashvili A.G., Kartvelishvili L.G., Matzarakis A., Megrelidze L.D. The Statistical Characteristics of Tourism Climate Index in Kakheti (Georgia). Journal of the Georgian Geophysical Society, ISSN: 1512-1127, Physics of Solid Earth, Atmosphere, Ocean and Space Plasma, v. 21(2), Tbilisi, 2018, pp. 95-112.
10. Amiranashvili A., Kartvelishvili L. Statistical Characteristics of the Monthly Mean Values of Tourism Climate Index in Mestia (Georgia) in 1961-2010. Journal of the Georgian Geophysical Society, ISSN: 1512-1127, Physics of Solid Earth, Atmosphere, Ocean and Space Plasma, v. 22(2), 2019, pp. 68–79.
11. Kartvelishvili L., Amiranashvili A., Megrelidze L., Kurdashvili L. Turistul Rekreaciuli Resursebis Shefaseba Klimatis Cvlilebebis Fonze. Publish Hous "Mtsignobari", ISBN 978-9941-485-01-5, Tbilisi, 2019, 161 p., (in Georgian). http://217.147.235.82/bitstream/1234/293074/1/turistulRekreaciuli ResursebisShefasebaKlimatis-CvlilebebisFonze.pdf.
12. Scott D., Rutty M., Amelung B., Tang M. An Inter-Comparison of the Holiday Climate Index (HCI) and the Tourism Climate Index (TCI) in Europe. Atmosphere 7, 80, 2016, 17 p., doi:10.3390/atmos7060080www.
13. Öztürk A., Göral R. Climatic Suitability in Destination Marketing and Holiday Climate Index. Global Journal of Emerging Trends in e-Business, Marketing and Consumer Psychology (GJETeMCP). An Online International Research Journal (ISSN: 2311-3170), Vol: 4 Issue: 1, 2018, pp. 619-629.
14. Yu D. D., Rutty M., Scott D., Li S. A Comparison of the Holiday Climate Index: Beach and the Tourism Climate Index Across Coastal Destinations in China International Journal of Biometeorology, 2020, https://doi.-org/10.1007/s00484-020-01979-w, 8 p.
15. O. Cenk Demiroglu, F. Sibel Saygili-Araci, Aytac Pacal, C. Michael Hall, M. Levent Kurnaz. Future Holiday Climate Index (HCI) Performance of Urban and Beach Destinations in the Mediterranean. Atmosphere 11, 911; 2020, doi:10.3390/atmos11090911, 30 p.
16. Rutty M., Scott D., Matthews L., Burrowes R., Trotman A., Mahon R., Charles A. An Inter-Comparison of the Holiday Climate Index (HCI: Beach) and the Tourism Climate Index (TCI) to Explain Canadian Tourism Arrivals to the Caribbean. Atmosphere 2020, 11, 412.
17. Amiranashvili A., Kartvelishvili L., Matzarakis A. Comparison of the Holiday Climate Index (HCI) and the Tourism Climate Index (TCI) in Tbilisi. Int. Sc. Conf. „Modern Problems of Ecology", Proc., ISSN 1512-1976, v. 7, Tbilisi-Telavi, Georgia, 26-28 September, 2020, pp. 424-427.
18. Мезозавр. Статистическая система по анализу временных рядов. Руководство пользователя. Стат-Диалог, РАН, М., 1995, 141 с.

თბილისში დასვენების კლიმატის ინდექსის (HCI) ცვალებადობა

ამირანაშვილი ა., ქართველიშვილი ლ., მატზარაკისი ა.

რ ე ზ ი უ მ ე

წარმოდგენილია დეტალური ინფორმაცია თბილისში 1956-2015 წლებში დასვენების კლიმატური ინდექსის (HCI) ყოველთვიური მნიშვნელობების ცვალებადობის შესახებ. ასევე მოცემულია მონაცემები HCI-ს მნიშვნელობების ცვალებადობის შესახებ მომდევნო რამდენიმე ათწლეულის განმავლობაში ინტერვალური პროგნოზის საფუძველზე.

საკვანძო სიტყვები: დასვენების კლიმატის ინდექსი.

CHANGEABILITY OF THE HOLIDAY CLIMATE INDEX (HCI) IN TBILISI

Amiranashvili A., Kartvelishvili L., Matzarakis A.

A b s t r a c t

The detailed information on the variability of the monthly values of the Holiday Climate Index (HCI) in Tbilisi in 1956-2015 are presented. It also presents data on the interval forecast of variability of HCI values in Tbilisi for the next few decades.

Key words: Holiday Climate Index.

ИЗМЕНЧИВОСТЬ КЛИМАТИЧЕСКОГО ИНДЕКСА ОТДЫХА (HCI) В ТБИЛИСИ

Амиранашвили А., Картвелишвили Л., Матзаракис А.

Р е ф е р а т

Приведена подробная информация об изменчивости месячных значений климатического индекса отдыха (HCI) в Тбилиси в 1956-2015 гг. Также представлены данные по интервальному прогнозу изменчивости значений HCI в Тбилиси на ближайшие несколько десятилетий.

Ключевые слова: Климатический индекс отдыха.