

Bioclimatic diversity of Bulgaria: a resource or a limiting factor of the recreation & tourism?

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Abstract

Placed along the middle latitudes, the territory of Bulgaria combines climatic features of far more northern and southern placed areas. The general influence of the solar and circulatory factors on the climate of this small territory is combined with the specific impact of the local physical-geographical factors, represented by the high mountain systems as Rila, Pirin, Rhodopy, Balkan, etc., as well as the basin of Black sea too. The influence of these factors induces considerable seasonal and space climatic differences, varying from tropical to arctic climates. What is the role of the corresponding bioclimatic diversity for the recreation and tourism? This paper seeks for an answer of this question, basing on the method of the heat balance of the human body. On this base it is established, by indexes like “a heat load of an organism” or “a space bioclimatic contrast”, etc., that the bioclimatic diversity on the territory of Bulgaria varies from “thermal-neutral conditions” to “extreme heat stress” (both a stress from overcooling and overheating). However from the point of view of recreation-and-tourism the next fact is of an importance: in any given period of the yearly climatic cycle there are places of the territory of Bulgaria which are distinguished by favourable bioclimatic conditions. But the planning of an optimal recreational&tourist activity requires a close preliminary bioclimatic reference, both in macro- and in mezo-/micro-scale. In other case a risk to fall in a discomfort bioclimatic situation is quite possible here any time at given place, and any place at given time.

Keywords: Bioclimatic diversity, Human heat balance, Bioclimatic confort/discomfort, Bioclimatic “identity card”, Bioclimatic network.

Introduction

The geographical location of Bulgaria on the edge between the mid-latitudes and the subtropics determines significant climatic diversity of it's territory. As a rule the climate of Bulgaria is formed mainly under the influences of the mid-latitude air masses, in the system of the West-East zonal air transfers. However this rule quite often gets broken by the meridional forms of an atmospheric circulation, which provide a North-South direction of an air exchange. Within the frame of this exchange the territory of Bulgaria very often gets affected both by tropical and by arctic air masses. That is why, at the

typical for these latitudes solar radiation conditions, the climate of Bulgaria combines features which are specific for far more northern and more southern climates.

An additional factor which reinforces the climatic diversity of Bulgaria is the physical-geographical characteristic of its territory, which possesses quite specific peculiarities (fig.1).

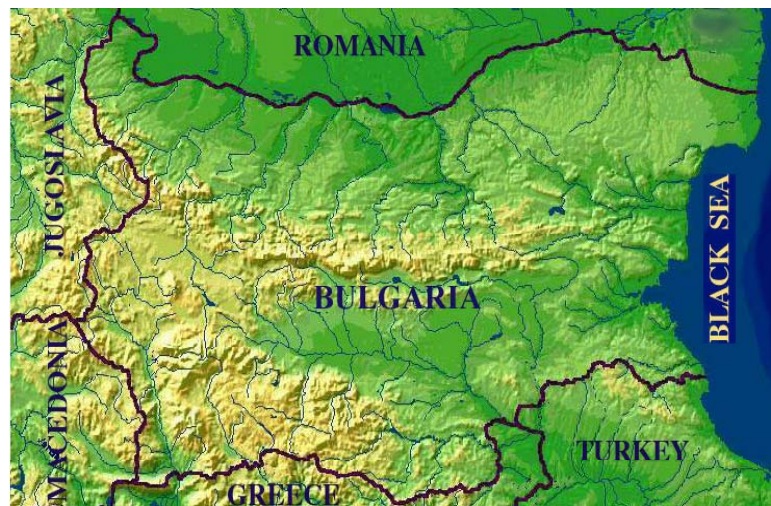


Fig. 1 Physical-geographical map of Bulgaria

The broadly-opened territory to the north - north-east, as well as the orientation of the big river valleys of Maritza, Struma, Mesta, etc., to the South - South-east, foster the North-South air access. The high mountain systems of Rila, Pirin, Rhodopy and the Balkan disrupt the natural horizontal climatic zonality, generating vertical climatic belts. The highest elevations of these mountains are characterized by specific climatic features similar to the features of the high latitudes of the planet. The lowlands, the hollows and the valleys closed between the mountains, enhance the climatic continentality of Bulgaria, and the Black sea basin moderates its climate.

For examples, about 10% of the days in summer at places along the Southern Black sea coast, or along the big rivers/lakes from the internal parts of the country, are known by wet-tropical type of weather, according to the Choubukov classification (Tishkov 1968). This type of weather is described by average diurnal air temperatures above 27.4°C , in combination with a relative humidity of an air above 81%. On the other hand about 70% of the days in winter at the high mountain levels in Bulgaria are described as “ice days”, i.e. they show negative diurnal temperatures, and this is valid for the average values, as

well as for the minimal and the maximal values too (Tishkov 1972). These mountain places are specific by “very high” degree of Bodman’s weather severity index (Mateeva 2001). However, in the same time, many parts of the country keep “neutral” bioclimatic conditions in different periods of the year.

This quite motley climatic picture of Bulgaria appears as some more motley bioclimatic picture, grading from indifferent to extreme extents of the bioclimatic scales (as at an overheating so at an overcooling of the human organism).

What is the extent to which the bioclimatic diversity of Bulgaria stimulates the recreation&tourism and what is the share of it’s limiting role?

This study is trying to give an answer of this question by making a specific assessment of the bioclimatic conditions in Bulgaria, differentiating them by space, and by seasons.

Methods

In this work the influence of the climate on the human biocomfort is studied by the method of the human heat balance. The method concerns the heat equilibrium of the human organism “which is a basic requirement for keeping constant core temperature and preconditions good physical and mental health” (Blazejczyk, Krawczyk 1994). The adaptation of the method to the open air conditions creates possibilities of it’s use to investigate the climatic influence on the human activity in the open, including on the recreation&tourism.

We have used the following model of a heat exchange between the human body and it’s surroundings (Licht, Sidney 1964), (Blazejczyk 1994):

$$BMR+WL+R +C+E+L+Res=S$$

where:

BMR	Basal metabolic rate
WL	Metabolic heat production due to physical activity
R	Solar radiation absorbed by a clothed man
C	Heat exchange by convection (i.e. turbulent exchange of sensible heat)
E	Heat loss by evaporation (i.e. turbulent exchange of latent heat)
L	Heat exchange by long-wave radiation
Res	Heat loss by respiration
S	Net heat storage

The BMR, WL and R are the import heat sources to the human organism whereas the C, E, L and Res are the sources of a heat export from the organism. In specific meteorological situations when the air temperature is higher than the skin temperature, a slight income of a heat by C or by L is observed (Blazejczyk 1993). Heat losses due to conduction, or by the excretory system of the organism are insignificant, so they are not considered in this model.

The calculations are made by the algorithmic system of the MENEX model (Blazejczyk 1994). The following indices, calculated mostly by this model are used in this paper :

- Thermal sensation (TS)
- Heat load (HL)
- Bioclimatic contrast (BD)
- Optimal clothing (ICL)
- Maximal time of exposure (MTE)
- Optimal work load (OWL)

The above indices are calculated at a standard insulation of a clothing of 1 clo and at a work load (physical activity) of 70 W.m^{-2} . As the recreation&tourism activities take place mainly in the day hours, the indexes are calculated by mean momentary values of the initial meteorological data (at the mid-day term of observation), 1941-1980. These indices, excluding ICL and OWL, are calculated at corresponding momentary skin temperature. The index of TS, as an index for general bioclimatic assessment, as well as a micro-bioclimatic index, is calculated both by the mean diurnal values of the initial meteorological data (at a constant skin temperature of 33^0 C), as by mean momentary data (at an inconstant skin temperature) too.

The results shown in this paper refer to representative months (January, April, July and October), and to representative meteorological stations from different types of the physical-geographical conditions in Bulgaria (table 1).

Table 1 Meteorological stations from different physical-geographical areas of Bulgaria, used in this study

Meteorolog. Stations	Altitude (m)	Latitude	Longitude	Physical-geographical conditions
peak Botev	2376	42⁰43'	24⁰55'	High mountains
Vezen	1800	42⁰46'	24⁰21'	Middle mountains
Samokov	1000	42⁰19'	23⁰34'	Low mountains
Sandanski	191	41⁰34'	23⁰17'	Valley opened to the Mediterranean
Plovdiv	160	42⁰09'	24⁰45'	Lowlands
Burgas	2	42⁰29'	27⁰29'	Seaside

Results

According to the de Freitas classification (Blazejczyk 1994), based on the net heat storage of the human body, the heat bioclimatic conditions, respectively the thermal sensations (TS) vary in the following scale: *very cold* ⇒ *cold* ⇒ *cool* ⇒ *temperate cool* ⇒ *comfortable* ⇒ *temperate warm* ⇒ *warm* ⇒ *hot* ⇒ *very hot*.

The bioclimatic conditions in Bulgaria, according to this classification, represent more narrow spectrum: *very cold* ⇒ *cold* ⇒ *cool* ⇒ *temperate cool* ⇒ *comfortable* ⇒ *temperate warm* (table 2).

This generalized bioclimatic picture of Bulgaria is based on average diurnal meteorological values. However, if we would consider the average mid-day meteorological values, when man usually realizes his activity in the open, we would find a quite more variegated picture of the bioclimatic conditions in Bulgaria. It's spectrum widens, crossing nearly all bioclimatic degrees, including the extreme ends of the bioclimatic scale: *very cold* ⇒ *cold* ⇒ *cool* ⇒ *comfortable* ⇒ *warm* ⇒ *very hot*. Based on the Blazejczyk classification (Blazejczyk 2001), this scale is applicable to the unstationary model of calculations, related to the momentary observations.

Table 2 Mean diurnal heat conditions (very cold, cold, cool, temperate cool, comfortable, temperate warm, warm, hot, very hot), at clothing insulation of 1 clo, at physical activity of 70 W.m⁻²

Months	Meteorological Stations					
	p. Botev	Vezen	Samokov	Burgas	Plovdiv	Sandanski
Jan	-748	-320	-206	-236	-212	-187
Apr	-498	-201	-98	-143	-69	-50
Jul	-257	-47	8	21	44	61
Oct	-383	-141	-79	-88	-46	-27
Legend:	v. cold	cold	cool	t. cool	com- fortab.	t. warm
		warm	hot	v. hot		

The diversity of bioclimatic conditions in Bulgaria, represented by the values of the net heat storage, respectively by TS, appears also by the structure of the heat exchange between human body and its surroundings. Specific differences of this structure emerge both seasonally and by space (fig.2). The main export share of the heat exchange in average annually has the heat lost by convection (C). In summer an increase of heat losses by evaporation (E) are observed though, and they become a main share of the heat export from the human body for the lowlands/hollows in Bulgaria. However in the mountains even in summer C remains the main export heat flux.

What is the heat load (HL) (Blazejczyk 2001) of an organism induced under the influence of the various heat conditions in Bulgaria? The results show that the HL differences in Bulgaria reach the maximal extent: from “an extreme stress of an overcooling” through “a comfort” up to “an extreme stress of overheating”, and this appears both territorially and seasonally. For example, in the summer on the highest mountain peaks of Bulgaria “extreme stress of overcooling” is observed (at a clothing insulation of 1 clo and a work load of 70 W.m⁻², at mid-day term of observation). At the same time, the middle- and the low mountain areas are characterized by “neutral” thermal conditions, the sea coast - by a “very small stress of overheating”, the lowlands from the internal country areas - by “an extreme stress of overheating” (fig.3).

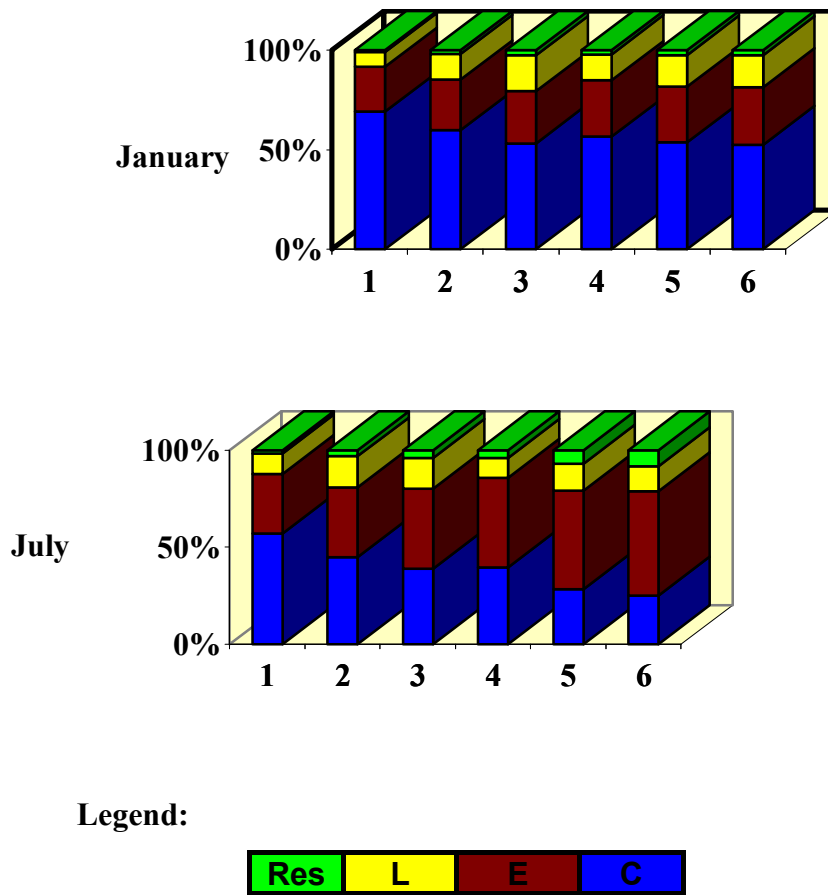


Fig. 2 A structure of the human heat balance: a share (%) of the lost heat fluxes (C-heat exchange by convection, E-heat loss by evaporation, L-heat exchange by long-wave radiation, Res-heat loss by respiration), compared to the total heat loss from the human body, for: 1-p.Botev; 2-Vezen; 3-Samokov; 4-Burgas; 5-Plovdiv; 6-Sandanski

Such significant variations of HL are observed also seasonally, but they are representative mainly for the lowlands/hollows of the country (for an example Plovdiv) (fig. 4). The sea coast areas and especially the mountains have considerably smaller seasonal fluctuations (fig.4a).

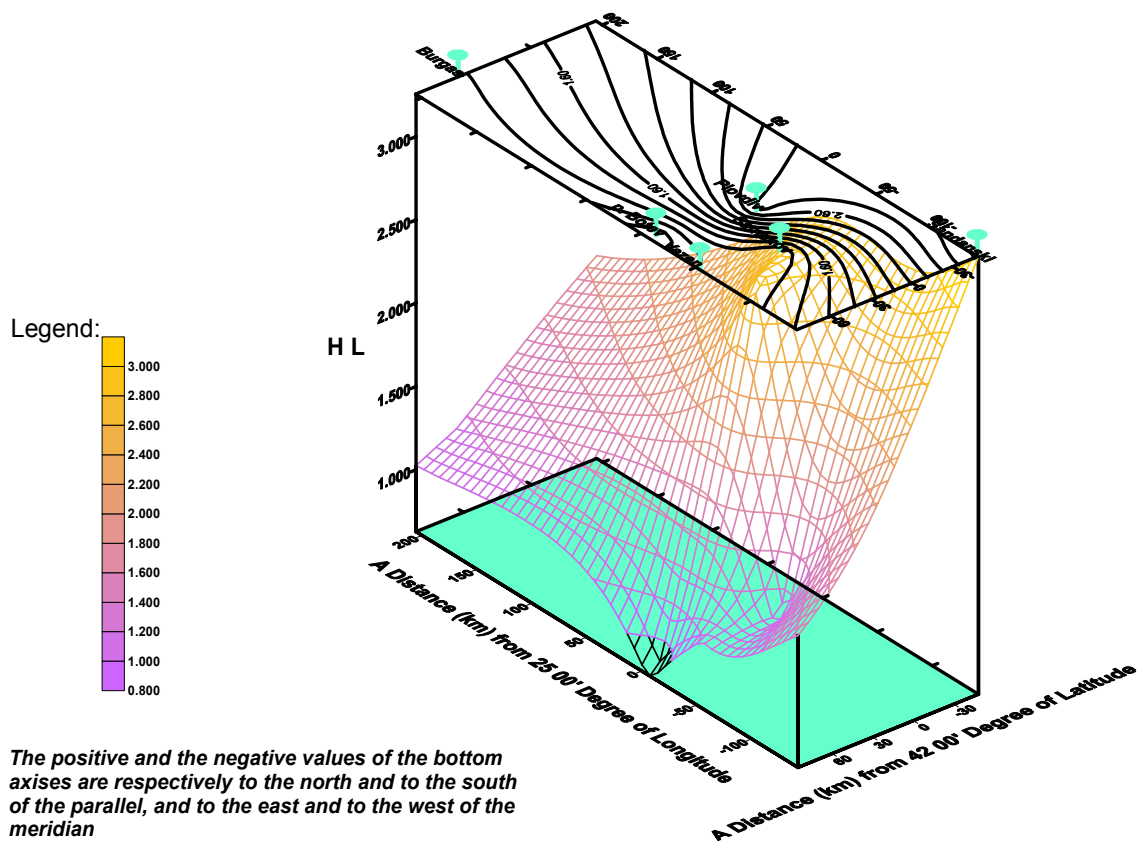


Fig. 3 Heat load (HL) of the human organism in July, at clothing insulation of 1 clo, at physical activity of 70 W.m^{-2}

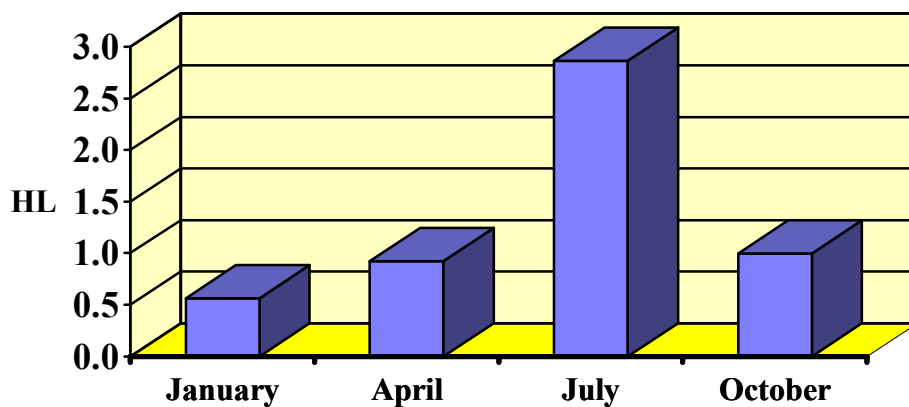


Fig.4 Heat load (HL) of a human organism in Plovdiv, at clothing insulation of 1 clo, at physical activity of 70 W.m^{-2}

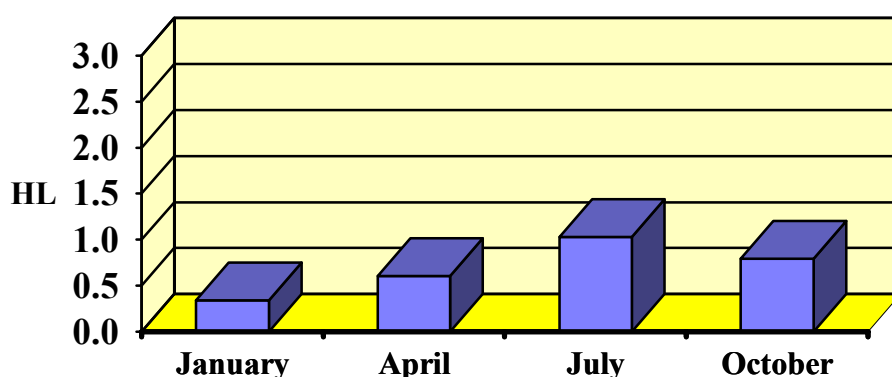


Fig.4a Heat load (HL) of a human organism at Vezen, at clothing insulation of 1 clo, at physical activity of 70 W.m^{-2}

The space and the seasonal bioclimatic differences in Bulgaria are illustrated by the index of a weather/climatic contrast (BD) (Rusanov 1996), (Mateeva 1997), (Mateeva, Filipov 2000), which shows the bioclimatic distances in the space (SBD), and by time (in this study by seasons) (CBD). Both SBD and CBD have the following grades: *optimal* (0.0 - 7.6) \Rightarrow *slight* (7.7 - 15.3) \Rightarrow *temperate* (15.4 - 30.7) \Rightarrow *sharp* (30.8 - 45.2) \Rightarrow *super-sharp* (>45.2). Table 3 indicates that on the territory of Bulgaria SBD varies from an “optimal” to a “super-sharp” extent. The seasonal bioclimatic distances (CBD) are also almost that expressive as the spatial ones. This is illustrated by table 4, for a meteorological station Plovdiv, representing conditions which are typical for a large part of the non-mountain territory of the country.

The considerable bioclimatic diversity of Bulgaria, illustrated by the results represented above, is a background for the following summary: any time of the year there are places on the territory of Bulgaria with extreme bioclimatic conditions, which limit the recreation&tourism. But in the same time there are any time places with mild bioclimatic conditions, stimulating the recreation&tourism. Examples for limitations are the highest parts of the mountains – almost during the whole year, and also the lowlands/hollows - in the summer and in the winter. Examples for stimulating conditions are both the Black-sea coast and the low/middle-mountain regions - in the summer, the southern valley areas opened to the Mediterranean basin - in the winter, and the whole territory of the country, excluding the high mountains - in the spring and in the autumn. However this general limits&stimuli bioclimatic picture is quite more diverse in terms of each

particular recreational&tourist site where a specific micro-bioclimate situation exists on the background of the macroclimatic one. A detailed and precise bioclimatic studies in mezo- and micro-bioclimate scale are needed to answer the concrete applied question: which is the right place and when is the right time for a recreation&tourism from the bioclimatic comfort point of view.

Table 3 Space bioclimatic distances in January and July

Legend:

July	January
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Met. Stations	P. Botev	Vezen	Samokov	Burgas	Plovdiv	Sandanski
p. Botev		52	62	59	63	65
Vezen	30		13	9	14	17
Samokov	40	19		5	1	4
Burgas	28	24	9		6	10
Plovdiv	46	30	17	9		3
Sandanski	46	30	17	9	0	

Table 4 Seasonal bioclimatic distances in Plovdiv

Months	January	April	July	October
January		27	43	25
April	27		32	3
July	43	32		35
October	25	3	35	

Discussion matters

This study brings up at least two groups of questions:

1. Methodical
2. Applied

The methodical questions are related to the human heat balance algorithmic system, used in this work. There are some problems which concern the unstationary approach of calculations, i.e. at inconstant conditions of a heat exchange between the human body





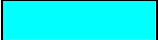

and its surroundings. The most significant of these problems is related to the calculation of the heat loss by an evaporation (E). The nonrealistic values of E at a very high skin temperatures have an effect on the net heat storage (S) values, and this reflects on the derivative indices, as well as on the relevant bioclimatic assessments. We have proposed some corrections of the formula of E (Mateeva 1997), which have reduced the problem to a certain extent, but we still consider this question remains as an open one.

The second discussion matter in this study has an applied character seeking for an answer of the question: How to conform the recreation&tourism by time and by space to the bioclimatic comfort, and how to reduce the bioclimatic discomfort in the cases when it inescapably appears? For countries with a considerable bioclimatic diversity like Bulgaria, this question takes a major importance. The optimization and planning of the recreational&tourist activity in the quite wide range between the extreme ends of the bioclimatic scales requires to know the means of the intentional thermal regulation for a reduction of a bioclimatic risk.

One of the most important regulators of the man's bioclimatic comfort is the clothing. By the clothing the perimeter of bioclimatic comfort may become considerably wider. This is shown on table 5, which presents the bioclimatic conditions in Bulgaria at a standard seasonal clothing (in comparison to a clothing of 1 clo on table 2). According to the International standards (ISO/DIS 9920) it is accepted in Bulgaria as a standard clothing insulation of 2 clo both in spring and in autumn, 1 clo in summer, and 3.3-3.5 clo in winter. By the index of ICL (Liopo, Tsitsenko 1971), (Blazejczyk 1994), (Mateeva 1996) we may calculate the values of the clothing insulation which reduce the bioclimatic discomfort to a comfort. So the index of ICL may be used both as a criterion for bioclimatic assessments, and also as a measure for the optimal clothing insulation at concrete weather/climatic conditions. Figure 5 indicates some places in Bulgaria where the values of ICL deviate from the standard values for each season, i.e. the places with an increased bioclimatic risk as well as the comfort places.

Table 5 Mean diurnal heat conditions (very cold, cold, cool, temperate cool, comfortable, temperate warm) at clothing insulation suitable to the season (compared to mean diurnal heat conditions at clothing insulation of 1 clo on table 2)

Months	Meteorological Stations					
	p. Botev	Vezen	Samokov	Burgas	Plovdiv	Sandanski
Jan	-228	-62	-25	-32	-25	-15
Apr	-260	-83	-23	-48	-5	5
Jul	-257	-47	8	20	44	61
Oct	-191	-48	-13	-15	7	18

Legend:		v.cold		t.cool
		cold		comfort.
		cool		t.warm

Another index of an applied importance for a reduction of the bioclimatic discomfort is an optimal work load (OWL) (Blazejczyk (1994), (Mateeva (1999)). It shows the optimal parameters of the physical activity at respective weather/climatic conditions, and at concrete parameters of a clothing insulation. This index gives various possibilities for a practical application, for example to project tourist trails with a definite optimal load of activity, depending on the preferences of the walking tourists, at a correspondent weather/climate. Table 6 shows that on the high mountains of Bulgaria a heavy physical activity is required during the whole year in order to maintain heat comfort (at a standard seasonal clothing). These are places appropriate for projecting of heavy tourist trails and activities, for example high mountain skiing, etc. On the other hand in the non-mountain areas of the country even the smallest physical work in summer causes a heat discomfort.

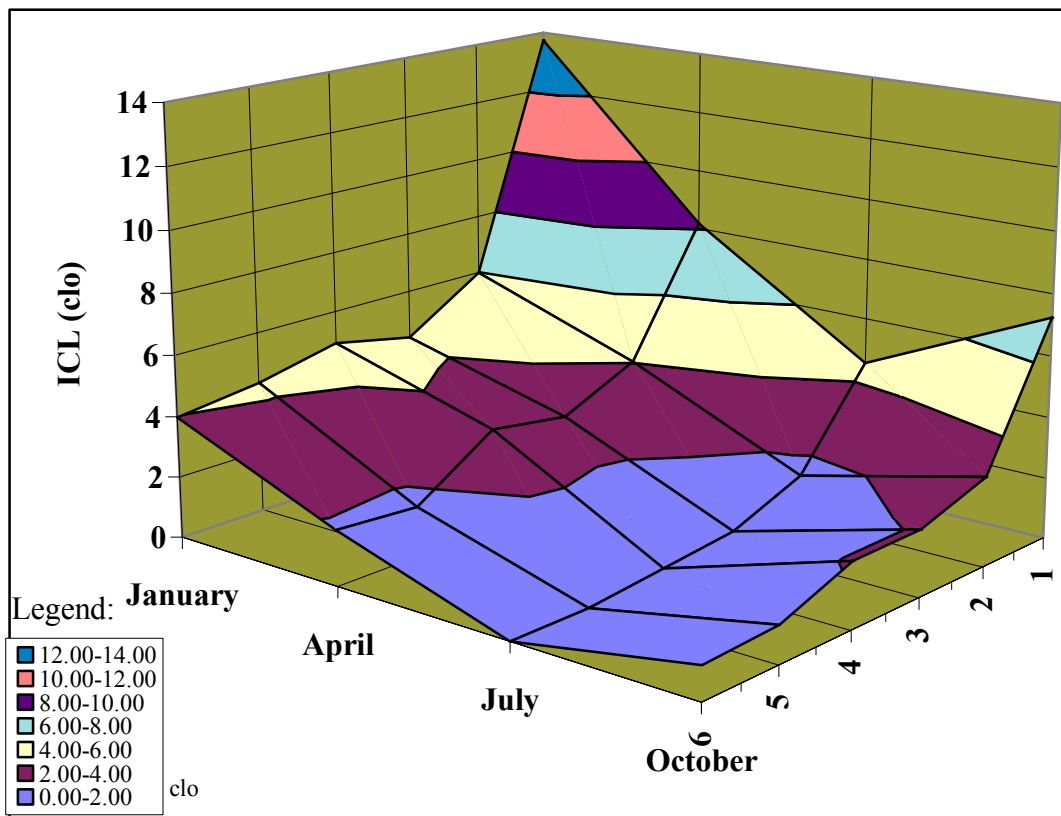


Fig.5 Optimal insulation of clothing (Icl), at physical activity of 70W.m-2, for: 1-p.Botev, 2-Vezen, 3-Samokov, 4-Burgas, 5-Plovdiv, 6-Sandanski

Table 6 Optimal work load (W.m-2), at clothing insulation of 1 clo

Months	Meteorological Stations					
	p.Botev	Vezen	Samokov	Burgas	Plovdiv	Sandanski
January	478	177	113	136	111	97
April	450	196	127	153	46	58
July	445	120	20	0	0	0
October	395	126	79	79	21	13

An index for reduction of the bioclimatic risk is also the maximal time of exposure in the open (MTE) (Blazejczyk (1994), (Mateeva (1997)). The results show that in Bulgaria the possibilities for non-risk stay of man in the open have an exceptionally high diversity. At clothing of 1 clo and work load of 70 W.m^{-2} MTE varies, depending on the season and on the place, from 14 min in winter (on peak Botev) to above a twenty-four-hour period in the autumn (in the lowlands) (fig.6).

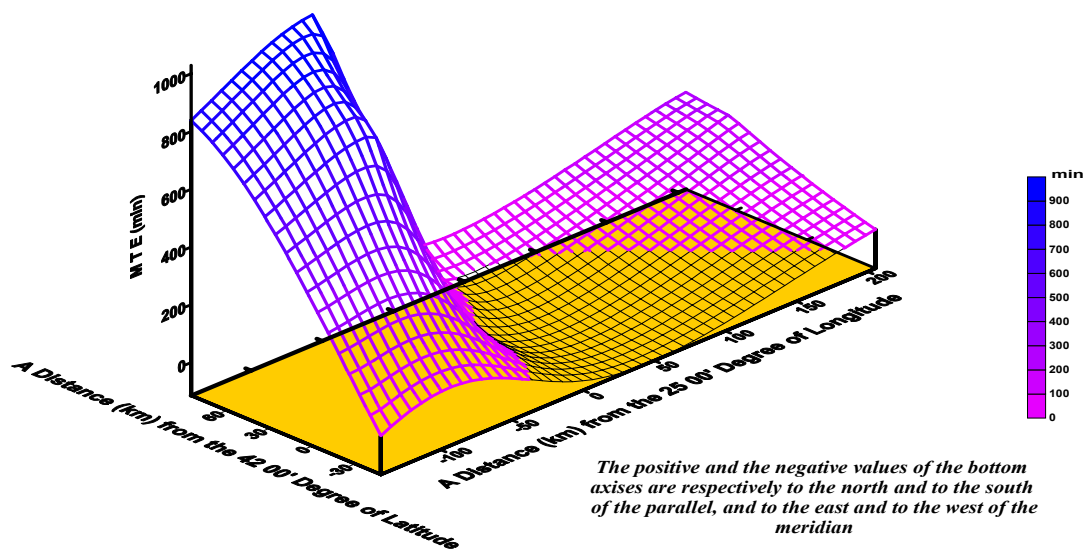


Fig. 6 Maximal time of exposure (MTE) in July, at clothing insulation of 1 clo, at physical activity of 70 W.m^{-2}

There are also a lot of other indices, based on the human heat balance which are of a great applied importance, especially for the recreation&tourism. Their calculation and use depends on the requirements of every particular recreation&tourism activity.

Recommendations

1. We would like to focus the attention of the scientific community to the algorithmic system of the human heat balance. We would focus our attention more to the problem of calculation the flux of the heat loss by evaporation (E), especially at an unstationary conditions of a heat exchange between the human body and it's surroundings.

2. It would also be useful the development of an unified, complex bioclimatic index which to integrate the different types of bioclimatic assessments: physical, physiological, psychological, etc. Such an index should has a multiple character, compound by multifarious criteria: for heat conditions; for physical limitations of the weather in open air, like rains, fogs, storms, etc.; for weather fluctuations (incl.assessments of it's contrasts and steadiness), etc.

We expect with a great scientific interest the results of the ISB commissions work, both the commission of "Development of a Universal Thermal Climate Index" and the commission of "Climate, Tourism and Recreation", which would combine the research efforts and achievements in this field by now, and would further develop them .

Based on such an unified index a bioclimatic "identity card" ("passport") should be developed for every recreational&tourist object. Bioclimatic "passportization" may has both climatic and meteorological aspect. The first one should be based on long standing climatic data, while the second requires an establishment of an operative bioclimatic monitoring (may be on the base of the meteorological network), providing current bioclimatic information, incl. the ways for a reduction of a bioclimatic discomfort (thus the bioclimatic limits may turn even into stimuluses).

On the base of the bioclimatic "passports" of the tourist&recreational objects a bioclimatic network may be built, both in national and in international scale, or by bioclimatic transects across the world physical-geographical regions.

The help and the encouragement of the international scientific community in establishment of a bioclimatic network may be a promising condition for an optimizing the recreational & tourist activities.

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