

## **THE HUMAN COMFORT CONDITIONS AT BULGARIAN BLACK SEA SIDE**

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**ABSTRACT** As Bulgaria becomes more and more integrated into the European Union, the tourism sector is expected to become a more important part of the economy. In order to determine sustainability of the tourism industry and to meet the needs of a fast and expansive development of tourism in Bulgaria, it is necessary to have detailed information about the climate potential and the length of the tourism season.

The aim of this work is to estimate the human comfort conditions in the Bulgarian Black Sea coastal area. The analysis is based on daily data from the Varna, Burgas and Ahtopol meteorological stations.

Different indexes such as SSI, THI, PMV and PET have been used to determine human comfort conditions. The results show that the region of the Bulgarian Black Sea is suitable for tourism and sport activities between April to October.

**KEYWORDS:** *Thermal comfort, bioclimate, tourism*

### **INTRODUCTION**

Since appearing on earth and up to now, human society has had to deal with weather and climatic changes. One of the socio-economic areas that is subject to the impact of atmospheric conditions is resort activity.

The present changes to the standard of living, cultural values, and transport development has lead to an increase in demand for weather information during the holiday season. So the necessity arises for timely, accurate and up to date information about local weather peculiarities of a specific resort.

Knowledge about the bioclimatic resources in turn allows for an optimal and profitable planning process and construction of resort areas. This considerably affects foreign currency revenue. Standard meteorological information quite often turns out to be insufficient for the aims of recreation and tourism.

The purpose of this work is to make an assessment of the bioclimatic conditions for some parts of the Bulgarian Black Sea coastal area using various complex estimates.

## **METHODS**

There are several theoretical and empirical indexes accounting for single or combined meteorological parameters, which give to some extent an assessment of the level of human comfort. Such approaches are covered in the works of many authors (Kyle, 1994, Matzarakis at al., 2004, 2007, Morabito and Bacci, 2003, Unger, 1999, Höpfe, 1999, Tzenkova et al., 2003). The most adequate thermophysiological assessment of the thermal environment can be done only on the basis of a complete heat transfer model of the man-environment system, accounting for all energy exchange mechanisms. Such models are MEMI (Höpfe, 1999), Klima-Michel-Modell (Jendritzky et al., 1990), PMV and PET (Matzarakis at al., 2007), among others. They are already used in practice. All these models require extensive meteorological input data (e.g. the values of radiation fluxes, data for human clothing and activity, etc.).

In this work four different methods are used for the assessment of human comfort conditions, all of which are frequently employed in various countries. This allows an easy comparison with already published results for other resort areas in the world.

### **Assessment of bioclimatic conditions by Thom index**

Thom index (THI) is determined by the formula (1)

$$\text{THI} = T - (0.55 - 0.0055\text{RH})(T - 14.5)^\circ\text{C} \quad (1)$$

where T is air temperature in °C and RH is air relative humidity.

THI index was initially used to determine discomfort due to “heat stress”, and was at a later stage assessed on a much wider range of meteorological conditions by Kyle (1994), and until today has been used by a number of authors (Unger, 1999, Morabito and Bacci, 2003, Tzenkova et al., 2003). The classification of the comfort level is based on the Besansnot classification scheme.

### **New summer heat index SSI**

The new summer index SSI (Summer Simmer Index) is a further developed version of Summer Comfort indexes, and was presented at the Meeting of the American Meteorological Society in Long Beach, California in July, 2000 as the New Millennium Index. It is derived from studies by the American Society of Heating and Refrigeration Engineers (ASHRAE) and

validated by tests and analyses done at Kansas State University over the past 75 years using the results of proven physiological models. This index is also determined on the basis of air temperature and relative humidity

$$SSI = 1.98 \cdot (Ta - (0.55 - 0.0055 \cdot Ur) \cdot (Ta - 58)) - 56.83 \quad (2)$$

where Ta is air temperature in degrees Fahrenheit and Ur is relative humidity (%)

### PMV and PET

PMV (Predicted Mean Vote) (Fanger, 1972) and PET (Physiologically Equivalent Temperature) are based on models of the human body energy exchange and are calculated using the RayMan model (e.g. Mayer and Höppe, 1987, Matzarakis et al., 2007).

The advantage of this model is that it uses air temperature and humidity as input information. Wind speed and radiation characteristics of the air are then calculated. The classification schemes of these indexes are given in Table 1.

**Table 1: Bioclimatic weather classes of the PMV and PET indexes**

PMV	PET	Physiological sensitivity	#
<-3.5	< 4	very cold	1
-3.5 ≤ PMV ≤ -2.5	4 ≤ PET ≤ 8	cold	2
-2.5 ≤ PMV ≤ -1.5	-8 ≤ PET ≤ 13	cool	3
-1.5 ≤ PMV ≤ -0.5	13 ≤ PET ≤ 18	slightly cool	4
-0.5 ≤ PMV ≤ 0.5	18 ≤ PET ≤ 23	comfortable	5
0.5 ≤ PMV ≤ 1.5	23 ≤ PET ≤ 29	slightly warm	6
1.5 ≤ PMV ≤ 2.5	29 ≤ PET ≤ 35	warm	7
2.5 ≤ PMV ≤ 3.5	35 ≤ PET ≤ 41	hot	8
3.5 ≤ PMV	41 ≤ PET	very hot	9

Daily climatological data from the stations in Varna, Burgas and Ahtopol for the period 1992 – 2006 and the synoptical data of Varna for the period 2001-2006 are used.

### RESULTS

The results are presented for each of the used indexes separately.

#### Thom's index - THI

The annual variation of THI indicates that there is a stable formation of comfortable weather conditions along the entire coastline of the Black Sea starting in the beginning of the second week of May. This weather condition persists until the beginning of the second week of

October. Considering that cool weather is favourable for active outdoor sports activities and is also preferred by elderly people, the resort season lasts from the end of April to the third week of October.

The analysis of the distribution of comfort classes shows that comfortable weather dominates in May, June and September (Fig.1). In July and August, hot weather is registered at all stations in more than 90 % of observed cases and 50 % of people feel discomfort. This type of weather is very suitable for healthy people when going to the beach or undertaking related activities. Children and people with health problems should do sports activities in the remaining months of the season.

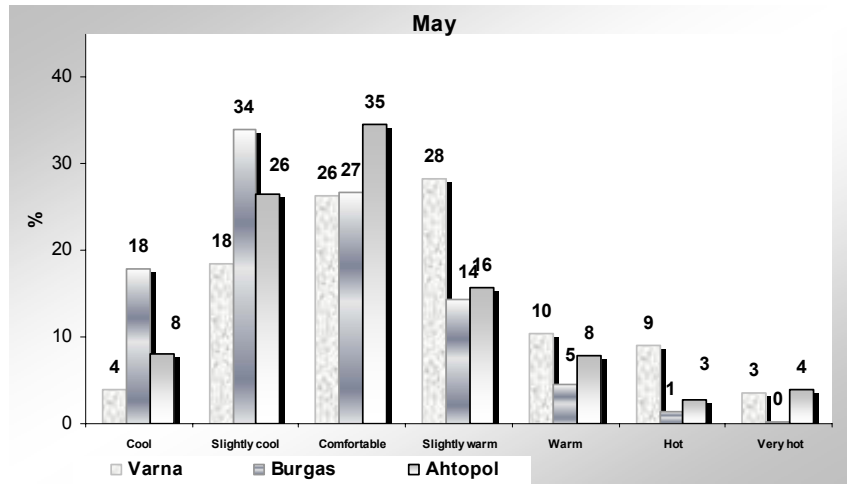
### **New Summer Simmer Index SSI**

In the period 1992 – 2006, according to the mean diurnal values of SSI from May to September the comfortable weather begins on the 10<sup>th</sup> of July and changes to cool by mid-September. For the majority of the season (May – September) the values of SSI are in the range 83-90 (F°), a level that most people perceive as warm. Sporadically, the weather in Varna and Burgas is hot. One should have in mind that the stations in Varna and Burgas are urban stations and thus have warmer weather. In the seaside resorts destinations where no anthropogenic effects take place, conditions are expected to be mostly comfortable. During the last 15 years, people acclimatized to warmer climate along the Black Sea coast, did not perceive the weather as uncomfortable.

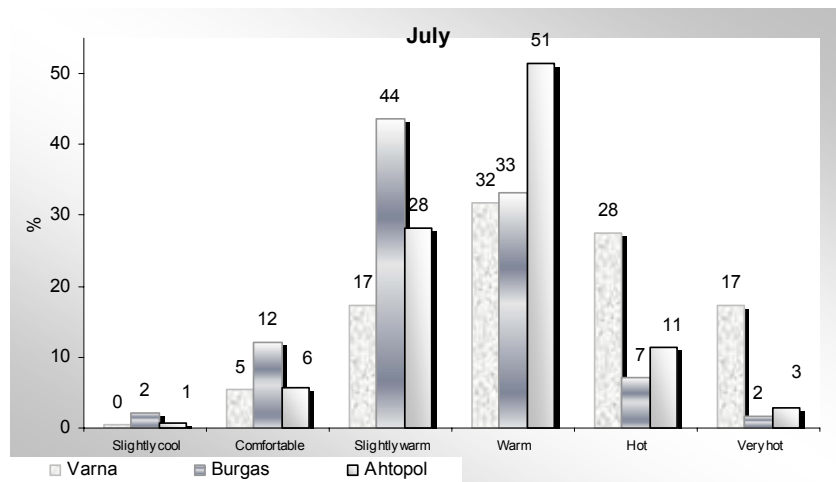
Tourists are concerned with the bioclimatic conditions at different times of the day. From mid-June until mid-August, at 7:00 and 21:00 warm weather prevails and only on 13% of all summer evenings is the weather in Varna perceived as hot. At Ahtopol station there are no such evenings, according to the average values for the period. At 14:00, the weather is perceived as hot and results in discomfort (SSI is in the range 91-100 F°). This situation remains for almost the entire summer season. The risk of thermal stroke and exhaustion is present on only 16 % of all days in the study period in Varna and Burgas. This risk is due to long exposure to sun and intensive physical activity.

### **PMV and PET indexes**

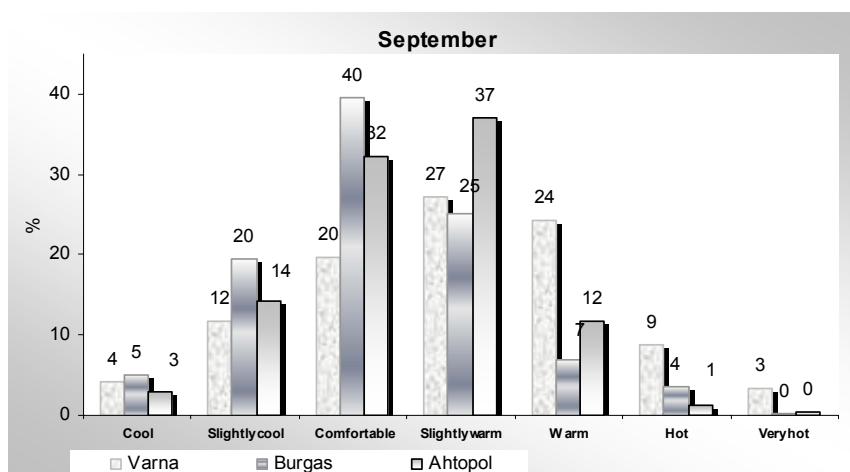
Indexes considered before, fail to account for the effect of shortwave and long wave energy fluxes on human body. This data is usually not included in meteorological databases, but can be calculated from the data. The estimate Predicted Mean Vote (PMV) and Physiologically Equivalent Temperature (PET) measure the thermal effect of the environment on human beings.



a)



b)



c)

Figure 1: The distribution of the comfort conditions according PET for 14h for 1992-2006 : a) May, b) July, c) September

Considering also the mean monthly values of these two indexes, May and September appear predominantly cool, while summer months are mainly comfortable. Based on the mean monthly values, July and August can be defined as warm (i.e. people experience slight heat stress).

In order to estimate the probability of extreme heat stress, we did a more detailed analysis of PET for 14 LST. The distribution of the comfort classes by month for the period from May to September for the years 1992 – 2006 is shown in Figure 1 a-c.

In May the frequency of comfortable weather in Varna and Burgas is measured for 26-27 % of all days, and in Ahtopol – 35 % of all days. Slight to moderate heat stress exists on 38 % of the days in Varna, while in Burgas and Ahtopol it is on 19 % and 24 % of days respectively. As seen in Figure 2.a, in May, the people in Varna are subject to heat stress of various degrees at noon in about 1/3 of the days. The situation in Ahtopol is similar, while in Burgas such cases were not observed.

In June comfortable or slightly warm weather prevails in Burgas and Ahtopol, whereas in Varna people are subjected to heat stress on most days (moderate 35%, strong 16% and extreme 9 %).

During the hottest summer month (Fig. 1 b) the conditions at the station in Burgas are most favourable. The weather is comfortable or slightly warm on 56 % of days. Heat stress varies from moderate to strong on the remaining days. In Varna thermal conditions are most unfavourable at these hours. Strong (28 %) or extreme (17 %) heat stress is present on 45 % of all days. In Burgas and Ahtopol extreme heat stress is rarely observed in the period of study. In August the thermal conditions are similar to those in July, despite the high frequency of possible heat stress at 14 LST. Such weather is very suitable for water sports done by young and healthy persons, while children and elderly people should avoid long stays outdoors during this time of the day.

Typical summer conditions are observed in September with comfort levels ranging from warm to very hot (36 % for Varna and 13 % for each Burgas and Ahtopol) (Figure 1.c).

The values of PET for 14:00 for the period 2000 – 2006 are determined to allow an estimate of the trends of bioclimatic conditions in the considered region. Significant differences were not registered for all stations. Figures 2 a and b show a general estimate of the bioclimate in the region of Varna based on the mean monthly values of PMV and PET, by year, for the period from 2000 to 2006.

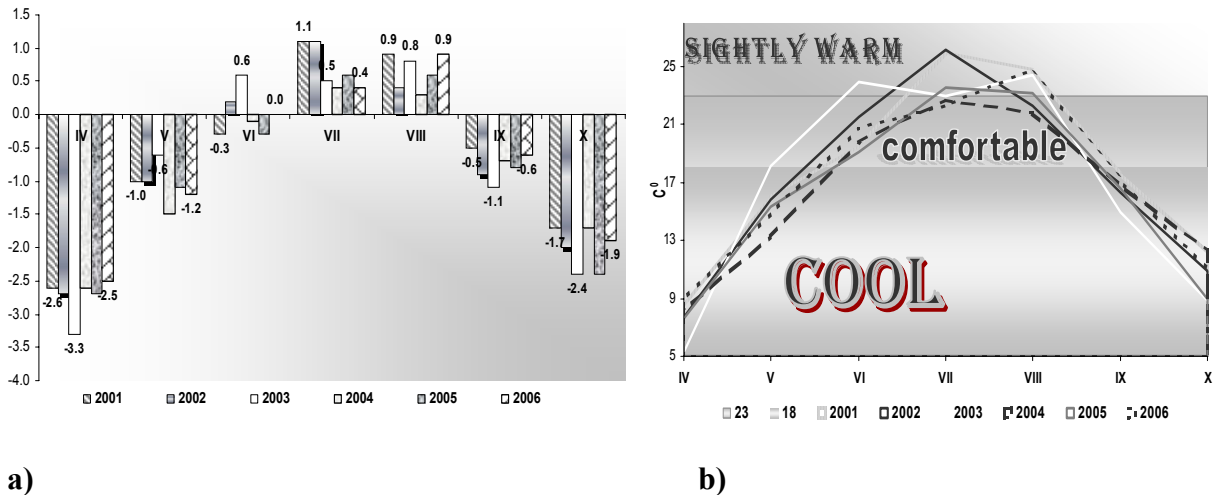


Figure 2: Monthly average values of PMV a) and PET b) for the tourist season 2001-2006

## CONCLUSIONS

The presented analysis of the different comfort indexes shows that the bioclimatic conditions on the Bulgarian Black Sea are very comfortable. According to our data analysis the resort season starts in the second week of May, when comfortable weather conditions begin to remain stable, and continues until the beginning of the second week of October.

Based on the daily data, the climate in the coastal strip is mild and very pleasant for tourists, even in the hot summer months.

The small number of stations used and the insufficient representativeness of the station in Burgas, whose values are strongly affected by the surrounding park, do not permit a spatial assessment of the climatic resources of the Bulgarian Black Sea. The diurnal variation of the bioclimatic conditions needs to be specified and a more detailed knowledge of the climatic resources of the Bulgarian Black Sea is required.

To estimate the influence of climate change on bioclimatic conditions it will be useful to apply the results from climate change scenarios in order to make decisions for a sustainable future development of tourism in the study area.

While the work does not exhaust the issue of resource assessment, even at this stage the obtained results are comparable with those for other regions. The estimates are distributed worldwide and give a clear and comprehensive impression of the expected weather conditions in the seaside resorts to international tourists.

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