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BIOCLIMATE MAPS OF GREECE FOR TOURISTIC ASPECTS

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ABSTRACT. Based on the human energy balance equation the thermal index PMV *(Predicted Mean Vote)* can be calculated which allows the mean assessment of the thermal environment for a large sample of human beings in a thermophysiologically significant manner. Greece is a country with a complex topography resulting in distinct different regional climates. For selected synoptic stations of the Greek Weather Service, the daily 12 UTC values of PMV were calculated for the period 1980 until 1989. With the help of a statistical model, PMV values of individual stations were transferred into high resolution bioclimatic maps of Greece. The analysis of the human-biometeorological conditions shows no thermal stress in winter in most parts of Greece. In summer, at least strong heat stress occurs at noon in the interior and in lower located regions of Greece which are more far from the coast. A comparatively lower heat stress is at that time on the islands and in the coastal regions, because they are influenced by Etesian winds or local circulation systems. In summer human beings have comfortable thermal sensations only in the higher located parts of Greece.

Key words: Predicted Mean Vote, heat stress, bioclimate maps, Greece

1. INTRODUCTION

The atmospheric environment has different effects on human beings. They can be divided into some effective complexes which are one topic of research in human-biometeorology. Thermal effective complex and air pollution effective complex are most important from the point of view of meteorology.

While the air pollution effective complex is more relevant to urban and landscape planning in Central Europe, thermal effective complex has serious consequences for human beings in the Mediterranean area. Therefore, the investigation of the thermal effective complex in Greece is of great interest especially in touristic aspects, too, because tourism is a leading economic factor in this country. Results of the investigation of the thermal effective complex may be the basis in order to reduce or extend the holiday period, for the decision in which region overwintering is best, or for identifying the regions with extreme heat stress in summer (Giles and Balafoutis, 1990, Giles et al., 1990, Matzarakis and Mayer, 1991)

2. METHOD

The thermal effective complex consists of meteorological parameters that affect the human being in thermophysiological terms. These parameters are air temperature, air humidity and wind speed, as well as short- and long-wave radiation which are parameterized by the mean radiation temperature. The significance of the thermal effective complex to human health is closely related to the thermo-circulatory system of the human body.

Past human-biometeorogical studies have been based on indexes which consist only of a single meteorological parameter or a combination of them. A major disadvantage of these indexes is their lack of physiological relevance. The currently more popular thermal indexes (e.g. PMV), by contrast, do have physiological relevance, being derived from the parameters of the human energy balance. A fundamental energy balance equation for human beings, the comfort equation, was described by Fanger (1972). The 'Klima-Michel-Model' (KMM) incorporates the comfort equation with approaches for short- and long-wave radiation fluxes, as shown in several applications (Jendritzky et al. 1990, Mayer 1993 and 1996). The calculated PMV value *(Predicted Mean Vote)* represents the average assessment of the thermal environment for a large sample of human beings according to a comfort scale (Table 1).

In the present study, PMV values for selected synoptic stations of the Greek weather service (Fig. 1) were calculated for the period January 1, 1980 to December 31, 1989. Because of the necessity to analyze extreme thermal conditions, only meteorological data of observations at 12 UTC were utilized. The preparation of air temperature, water vapour and wind speed data for the use in the 'Klima-Michel-Model' posed no difficulty. But to include short- and long-wave radiation, a radiation model needed to be developed. It provided the mean radiation temperature as the additional meteorological input parameter for the 'Kima-Michel-Model' (Jendritzky et al. 1990, Matzarakis, 1995).

Table 1 Thermal index PMV *(Predicted Mean Vote)*, thermal sensation and physiological stress level - modified by Mayer (1996) after Jendritzky et al.(1990)

PMV	thermal sensation	physiological stress level
	very cold	extreme cold stress
-3.5		
	cold	strong cold stress
-2.5		
	cool	moderate cold stress
-1.5		
	slightly cool	slight cold stress
-0.5		
	comfortable	no thermal stress
0.5		
	slightly warm	slight heat stress
1.5		
	warm	moderate heat stress
2.5		
	hot	strong heat stress
3.5		
	very hot	extreme heat stress

In addition to the meteorological parameters, the 'Klima-Michel-Model' requires the input of personal data. For this study, a human activity level of 80 W was chosen, which corresponds to light physical work. Clothing, with regard to its relevance to thermal resistance, was adjusted according to the governing meteorological conditions, with air temperature taken as the controlling factor. For the winter and transitional season, a daily thermal resistance value was derived which represented the thermophysiologically optimal clothing. For the summer season, a thermal resistance of 0.5 clo was determined, representing light summer clothing. These values were then integrated into the 'Klima-Michel-Model'.

3. RESULTS

The human-biometeorological assessment of the thermal environment at selected synoptic stations can be represented by bar graphs of daily PMV values. As an example, Fig. 1 shows the annual course of PMV at Rhodos which can be classified as a station with comparatively low thermal stress. In addition, Rhodos is one of the much-frequented islands in Greece. The highest PMV value has been 6.0 (extreme heat stress) in summer, the lowest -1.0 (slight cold stress) in winter. PMV values above 4.0 were not frequent in summer.

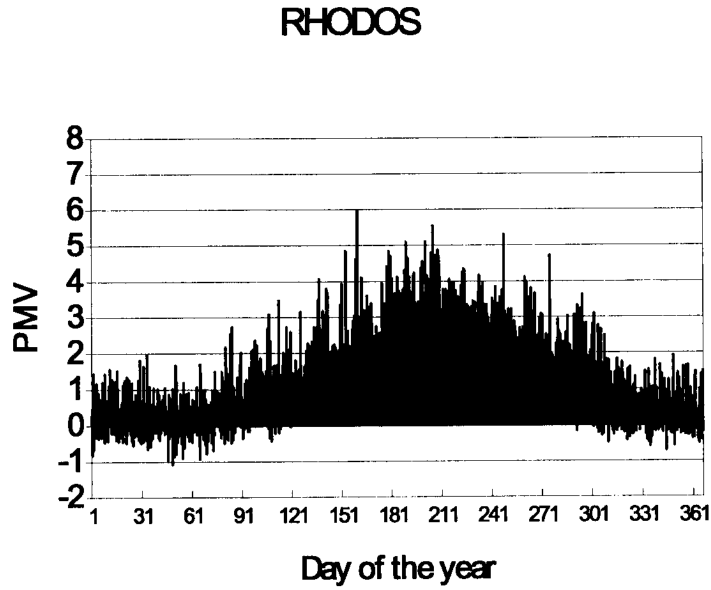

Fig. 1 Daily PMV values at 12 UTC at Rhodes station: the individual PMV values for each day for the period 1980 - 1989 are shown

In Table 2 the average monthly numbers of days with classified PMV values for Rhodos are given. They show no days with PMV values below -1.2. Days with slight cold stress are not frequent. Noticeable is that in the cold season (December until March) human beings have comfortable thermal sensations at noon on more than two-thirds of all days. PMV values between 0.6 and 2.0 (slight and moderate heat stress) can be found at Rhodos station during the whole year, but most frequent in the warm season. Strong heat stress is characteristic of more than half the days in July and August. Few weather situations with extreme heat stress are limited to the period from June until September.

Compared to other regions in Greece (Matzarakis and Mayer, 1991, Matzarakis et al., 1994, Mayer and Matzarakis, 1996), Rhodos has a low heat stress level in summer. This is due to the influence of cool, dry Etesian winds which are very strong in this part of the Agean Sea (Arseni-Papadimitriou, 1984).

Table 2 Average monthly numbers of days with classified PMV values at Rhodos station for the period 1980 - 1989

	PMV classes							
	< -1.2	-1.2 - -0.6	-0.5 - 0.5	0.6 - 1.2	1.3 - 2.0	2.1 - 3.0	3.1 - 4.0	> 4.0
Jan	0.0	0.2	24.0	5.4	1.4	0.0	0.0	0.0
Feb	0.0	0.7	23.6	3.5	0.5	0.0	0.0	0.0
Mar	0.0	0.3	21.1	8.0	1.3	0.3	0.0	0.0
Apr	0.0	0.0	9.1	13.6	6.3	0.8	0.2	0.0
May	0.0	0.0	1.3	9.5	17.0	2.3	0.8	0.1
Jun	0.0	0.0	0.0	0.5	15.5	11.1	1.9	1.0
Jul	0.0	0.0	0.0	0.0	4.4	18.0	6.7	1.9
Aug	0.0	0.0	0.0	0.0	2.7	20.0	7.8	0.5
Sep	0.0	0.0	0.0	0.1	14.5	13.4	1.8	0.2
Oct	0.0	0.0	1.1	8.9	16.9	3.2	0.8	0.1
Nov	0.0	0.1	14.5	11.6	3.5	0.3	0.0	0.0
Dec	0.0	0.1	23.5	5.7	1.7	0.0	0.0	0.0

The results given for the selected synoptic stations in Greece such as Rhodos allow a human-biometeorologically significant analysis of the varying thermal conditions at individual sites. Moreover, there is a great need for spatial information on thermophysiologically relevant indexes. For this purpose, bioclimatic maps have to be generated that display, for example, the spatial distribution of PMV values. Individual PMV values were charted on a map using a statistical model that also required non-meteorological data like topographic data. For this purpose, a digital relief model of Greece with a resolution of one minute - equivalent to a resolution of 1.8 km * 1.3 km for Athens - was developed (Matzarakis, 1995). Topographical factors like slope exposition and slope angel were derived from this model.

A methodology linking meteorological data with geographical data in order to generate a spatial approximation of PMV values by use of the PMV results for the selected synoptic stations was developed with the help of multiple linear regression (Jendritzky et al., 1990). For each grid area, the PMV values were calculated as a function of latitude, continentality, height above sea level, slope exposition and slope angel, as well as ratio of sea and land surface. The results are monthly bioclimate maps for Greece (Matzarakis, 1995).

Most parts of Greece show no thermal stress in winter (December, January, and February). Slight and moderate cold stress occurs only in northern regions above 450 m asl and in still higher southern regions. Strong cold stress is limited to some areas which are located above 1800 m asl.

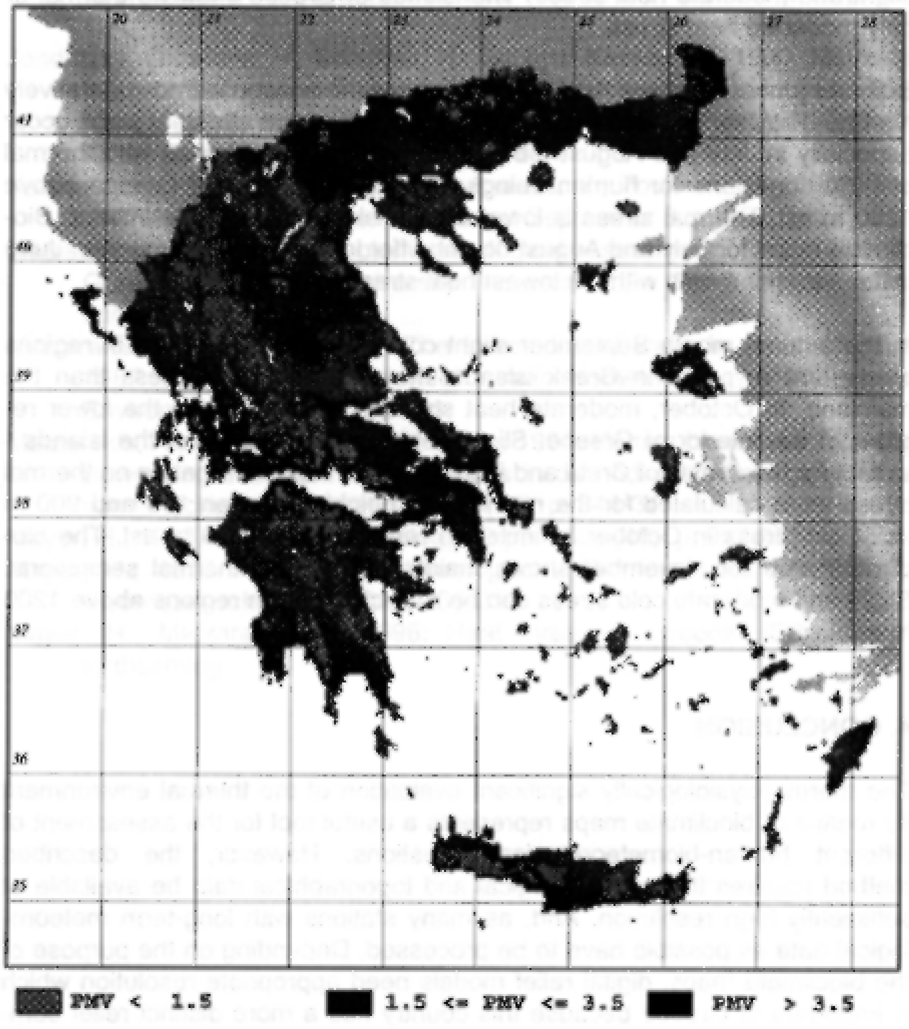

Fig. 2 Bioclimate map of Greece for August

In spring (March, April, and May), bioclimate maps of Greece are different between each month. Coastal regions and islands reveal no thermal stress. Slight and moderate cold stress is felt in areas above 900 m asl. In April, the region with slight and moderate cold stress lies above 1200 m asl, whereas most of the other parts of Greece are characterized by no or almost no thermal stress. Slightly higher PMV values are typical of lower regions with a greater distance to the coast. In May, the regions with no thermal stress have moved in heights above 600 m asl. Below this elevation are regions with slight and moderate heat stress. The islands of Greece show no thermal or only moderate heat stress.

Summer (June, July, and August) is in Greece the season with comparatively high heat stress. Weather situations with extreme heat stress at noon occur especially in July and August (see Fig. 2 for August). Regions with thermal comfort conditions for human beings are limited to parts of Greece above 1200 m asl. Thermal stress is lower on the islands than in the interior. Bioclimate maps for July and August do not differ in a remarkable manner. June is the summer month with the lowest heat stress in Greece.

In the autumn month September slight cold stress can be found in regions above 900 m asl. The Greek islands show a lower heat stress than the mainland. In October, moderate heat stress occur at noon in the lower regions in the interior of Greece. Slight heat stress is typical of the islands - except for the coasts of Creta and Rhodos. PMV values indicating no thermal stress were calculated for the mainland in heights between 150 and 900 m asl. Cold stress in October is limited to regions above 900 m asl. The bioclimate map for November shows mainly comfortable thermal sensations. Slight and moderate cold stress can be expected only in regions above 1200 m asl.

4. CONCLUSION

The thermophysiologically significant evaluation of the thermal environment by means of bioclimate maps represents a useful tool for the assessment of different human-biometeorological questions. However, the described method requires that meteorological and topographical data be available at sufficiently high resolution. And, as many stations with long-term meteorological data as possible have to be processed. Depending on the purpose of the bioclimate maps, digital relief models need appropriate resolution which is important of Greece because this country has a more distinct relief compared, for example, to Germany. Additional topographic factors like land use can be integrated into the statistical model to increase the information content with regard to the spatial approximation of PMV values.

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