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SYNOPTIC AND HUMAN-BIOMETEOROLOGICAL ANALYSIS OF THE HEAT WAVES IN GREECE

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ABSTRACT. The daily values (12 UTC) of the Predicted Mean Vote (PMV) thermal index were calculated over the Greek area, using the synoptic data of twelve selected stations for 10 years period (1980-89). The locally varied occurrence of diverse thermal sensation and particularly that of strong heat stress was analysed in human-biometeorologically significant terms. Nine episodes were recorded during the studied period. The prevailing synoptic conditions were almost similar during the episodes. The weather was generally was characterised by low wind speeds or calms, as well as negligible cloudiness. At the surface, any pressure gradient didn't exist and at the level of 500 hPa a subtropical ridge was covering the area. At the same level a trough of low pressure was appearing over west Europe from England to Spain. These synoptic conditions were responsible for the transportation of extremely warm air masses from north Africa to Greece.

Key words: Heat waves, Predicted Mean Vote, synoptic conditions, Greece

1. INTRODUCTION

The summers in Greece were often governed by meteorological conditions which are more or less uncomfortable to human beings. During the summers

of 1987 and 1988 Greece was plagued by two distinct heat waves resulting in death for about 2000 residents in July 1987 and about 40 residents in August 1988 in the greater area of Athens (Katsouyanni et al., 1988, Matzarakis and Mayer, 1991). Also, these two heat waves were studied by Giles and Balafoutis (1990) and Giles et al. (1990).

There is not any other analysis confronting the entire problem of the heat wave stress over Greece. Thus, our effort in this paper, is to give an subjective description of what exactly is a heat wave, to assessment all the heat wave cases during the studied period (1980-89) and to analyse the synoptic conditions responsible for the heat stress situations.

2. METHOD

Human-biometeorological studies on the effect of ambient thermal conditions on human comfort - referred to as the thermal effective complex - have been carried out during the past 50 years. 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. Their significance 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 like effective temperature or thermal stress index. A major disadvantage of these indexes is their lack of physiological relevance. The currently more popular thermal indexes, by contrast, do have physiological relevance, being derived from the parameters of the human energy balance. A fundamental human energy balance equation - 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 value Predicted Mean Vote (PMV) 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 were calculated for the period January 1, 1980 to December 31, 1989. Because of the necessity to analyse extreme thermal conditions, only meteorological data of observations at 12 UTC were utilized. In order 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 summer season, which is of our interest a thermal resistance of 0.5 clo was determined, representing light summer clothing. These values were then integrated into the calculations with the 'Klima-Michel-Model'.

3. RESULTS

Table 2 gives the average annual number of days with PMV values > 3.0 (strong and extreme heat stress) for all stations examined in the studied period. It demonstrates that strong and extreme heat stress occurs most often in Larisa (plain inland region) with 89.5 days and occasionally in Limnos (island of north Aegean sea) with 16.5 days. The frequency of strong and extreme heat stress days, at noon is decreasing in the order of: Larisa, Corfou, Florina, Samos, Hellinikon (Athen), Andravida, Tripolis,

Alexandroupolis, Mikra (Thessaloniki), Rhodos, Heraklion and Limnos. Hence it follows that thermal stress on human beings is lower on the islands or at the coastal regions than in the interior of Greece.

Table 2 Average annual number of days with PMV values > 3.0 (at least strong heat stress) at selected Greek stations for the period 1980 - 1989

station	latitude	altitude	elevation asl	PMV > 3.0
Larisa	39° 04' E	22° 25' N	73 m	89.5
Corfou	39° 37' E	19° 55' N	4 m	68.1
Florina	40° 47' E	21° 24' N	650 m	67.1
Samos	37° 42' E	26° 55' N	2 m	58.0
Hellinikon	37° 54' E	23° 44' N	28 m	47.9
Andravida	37° 55' E	21° 17' N	17 m	44.4
Tripolis	37° 32' E	22° 24' N	644 m	38.3
Alexandroupolis	40° 51' E	25° 57' N	7 m	38.2
Mikra (Thessaloniki)	40° 31' E	22° 58' N	4 m	35.0
Rhodos	36° 24' E	28° 05' N	4 m	23.8
Heraklion	35° 20' E	25° 11' N	37 m	21.3
Limnos	39° 53' E	25° 04' N	17 m	16.5

Under human-biometeorological aspects it is not enough to estimate only the average annual number of days with PMV values above a selected threshold value. The knowledge of consecutive days with PMV values above the threshold is also very important.

Table 3 shows the number of spells (at least three consecutive days) with PMV values > 4.0 at 12:00 UTC, for the selected Greek stations. On the basis of the calculated spells the results in Table 3 can be divided into three groups. The first group representing with high thermal stress, consists of the stations of Larisa (57), Florina (48), Corfou (36) and Samos (26). These stations located in the mainland with weak winds or high frequencies of calms. The second group contains the stations: Hellinikon (15), Tripolis (15), Alexandroupolis (15), and Andravida (10), which are coastal stations except of Tripolis. These stations have most frequent winds than the previous group. The stations Mikra (6), Limnos (5), Heraklion (3), and Rhodos (2) belong to the third group representing comparatively most favourable human-biometeorological conditions at stress situations. These stations are located on Aegian islands (the last three) or at coastal regions (Mikra) with good ventilation systems, as in Aegean sea the Etesian winds are the main climatic characteristic, during the warm period, and the local catabatic wind - named Vardaris - prevails in Mikra.

The subjective criterion to designate the heat wave was: the occurrence of PMV values > 4.0, for a period of at least 3 consecutive days, simultaneously in the 50 % of the stations under consideration (Table 3).

According to this limitation, nine heat waves identified during the decade 1980-89. They occurred primarily in the months of July and August, and also in the last week of June. These episodes took place in August 1980, end of June / beginning of July 1981, end of July 1981, mid-July 1984, end of July / beginning of August 1985, end of July 1987 (extreme heat wave in Athens with a large number of casualties), mid-August 1987, mid-July 1988 and beginning of August 1988. For the years 1983, 1986 and 1989 there were no periods that met the criteria for heat wave.

Table 3 Number of spells (at least three consecutive days) with PMV values > 4.0 (extreme heat stress) at selected Greek stations for the period 1980 - 1989

	year										
station	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**Sum**
Larisa	11	6	7	2	5	7	4	7	5	3	57
Florina	8	9	3	3	4	2	4	7	6	2	48
Corfou	2	6	3	3	4	7	3	3	1	4	36
Samos	2	4	1	1	2	3	5	5	3	-	26
Hellinikon	3	1	1	-	1	2	1	3	2	1	15
Tripolis	3	1	2	1	1	1	2	2	2	-	15
Alexandroupolis	1	1	2	-	-	4	1	2	4	-	15
Andravida	1	-	1	-	1	-	-	2	4	1	10
Mikra	1	1	-	-	-	1	-	1	2	-	6
Limnos	-	-	1	-	-	1	-	2	1	-	5
Heraklion	-	1	-	-	-	-	-	1	1	-	3
Rhodos	-	-	1	-	-	-	-	-	1	-	2

The identified heat waves were then analysed synoptically on the basis of the prevailing weather conditions over Europe using the European weather report of the German Weather Service. The synoptic situation of each episode was examined individually. The patterns of synoptic elements that encourage negative bioclimatic conditions were found to be similar during each heat wave episode.

An example of such a heat wave episode is given in figure 1. This episode occurred in the last days of June and first days of July 1981. The criterion given above was met by all stations except Alexandroupolis, Limnos, Andravida and Rhodos.

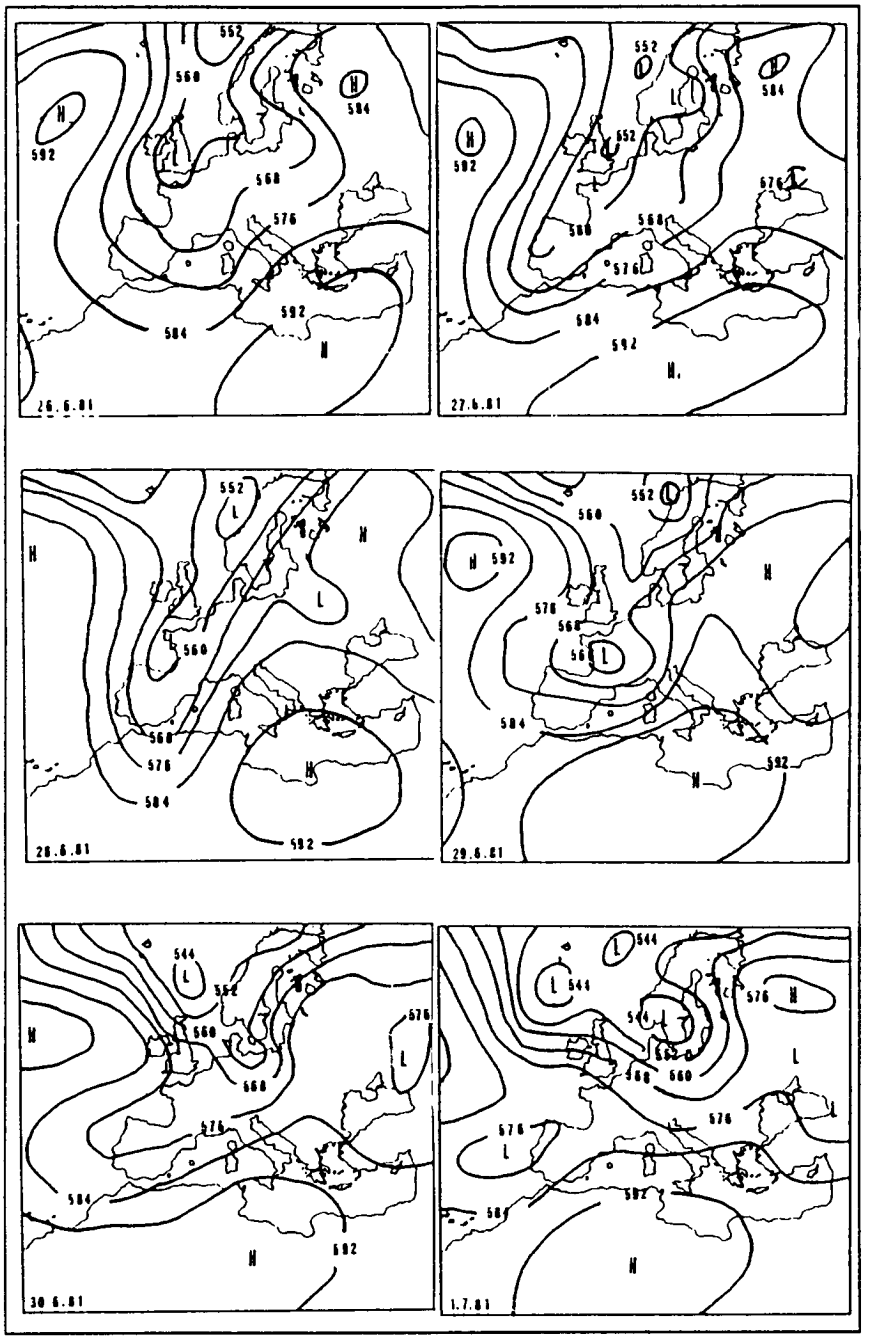

Fig. 1 Synoptic conditions at 500 hPa from 26.06. to 01.07.1981, 12 UTC

The synoptic analysis of the 500 hPa level map (Fig. 1) showed that during the period 26.6.-2.7.1981 Greece was under the influence of an African high-pressure ridge whose centre was located over Libya. The weather in most of western Europe was governed by a low-pressure trough extending from the polar circle via England and Spain to the Atlas mountains in north Africa. This synoptic combination encouraged the transport of warm, southwesterly air masses into the Greek region. Figure 1 shows analytically the synoptic conditions at the 500 hPa level for each day of the episode.

The analysis of the synoptic conditions at the surface for the whole period showed that the entire region was governed by a weak pressure gradient, resulting in light winds from variable directions, and mostly clear skies. A cold front which was located at the western Adriatic coast, did not influence Greece, as it moved northward.

The study of the eight remaining cases shoved that almost the same surface and upper-air synoptic conditions prevail during each episode. The upper air African ridge is the main factor of the heat wave appearance.

As it showed from the analysis of the nine episodes, it is clear that the intensity of the heat waves varies from station to station, depending of the position of the ridge, of the humidity aloft, and of the intensity of the descending mechanisms. Also apart of the synoptic conditions the local topography and mainly the presence or no of air pollution sources plays considerable role in heat wave results.

4. DISCUSSION AND CONCLUSION

According to the heat wave definition (three or more consecutive days with PMV > 4.0) Greece presents a considerable number of strong heat waves (almost one per year) producing negative effects to the population.
From the synoptic point of view the prevailing weather conditions, for each episode, showed similarities at the surface and the upper air levels. At the surface a weak pressure gradient existed with resulting variable light winds or calms and predominantly clear skies. At the 500 hPa level, the mean atmospheric flow was characterised by the extension of the north African anticyclone in the southern parts of the region and by low pressure centres to the west, usually in the form of extensive troughs over the western Europe. Occasionally, the north African upper air anticyclone developed a high-pressure ridge extending towards the Balkans. This combination caused warm dry air masses from Africa to reach Greece.

Apart of the synoptic situations very important is the role of the local factors including topographical characteristics, local wind systems, emission and accumulation of air pollutants and conurbation. These factors contribute significantly to the final result of a heat wave.

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