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Interdiurnal variability of sunshine duration in Greece

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The variations of the sunshine duration from one day to the next, which are known as interdiurnal variations, are studied for three meteorological stations in Greece, by using the same decade (1971–1980) data information. The stations used can satisfactorily cover the geographical area of Greece, since they lie on a meridional axis which extends all along the country. The study consists of the examination of the steady conditions, the rises and falls, as well as the variations irrespective of sign. The interdiurnal variation of sunshine duration shows generally higher values in the cold period than in the warm one, and, particularly, the months of April and May indicate higher values for the three stations. This finding is due to the interdiurnal cloud variation, which is more intense in the cold period and in northernmost station than in the warm period and in the southernmost station, and is related to the regime of the general atmospheric circulation over the Mediterranean area.

Međudnevna promjenjivost trajanja sijanja sunca u Grčkoj

Varijacije trajanja sijanja Sunca iz dana u dan, koje su poznate kao međudnevne promjene, razmatrane su za tri meteorološke stanice u Grčkoj, upotrebom podataka za istu dekadu (1971–1980). Stanice reprezentiraju geografsko područje Grčke, jer su smještene na meridionalnoj osi koja se proteže preko cijele zemlje. Proučavana su stacionarna stanja, porasti i padovi, kao i varijacije bez obzira na predznak. Međudnevne promjene trajanja sijanja Sunca općenito pokazuju veće vrijednosti u hladnom nego u toplom periodu; posebno su u travnju i svibnju vrijednosti visoke za sve tri stanice. Ova pojava nastaje zbog međudnevnih promjena naoblake, koje su intenzivnije u hladnom periodu i na najsjevernijoj stanici nego u toplom periodu i na najjužnijoj stanici, a povezane su s režimom opće cirkulacije atmosfere iznad Sredozemlja i okolnih područja.

1. Introduction

Sunshine duration has been recorded at he Greek meteorological stations for many years. The stations are spread all over the Greece, and their observations cover a period of fifty and more years, while station of the National Observatory of Athens covers a period of over a century.

Greece, like all the other Mediterranean countries, is characterized by extended sunshine duration, mostly due to its geographical location and characteristics of the general atmospheric circulation. This fact, together with the last-years exploitation attempts on solar radiation, mainly for economical and environmental purposes, secured the technological requirements suitable for detailed studies. Due to the fact that original data on solar radiation exist only for Athens while data on sunshine duration exist for the whole Greek area, a research attempt is made to study the interdiurnal variability (*ID.V.*) of sunshine duration, at three larger cities of Greece: Athens, Thessaloniki and Iraklion. *ID.V.* captures the irregular fluctuations of a climatic element from one day to the next. It is believed that these fluctuations, either smooth or abrupt, are important from climatological and exploitation point of view. The importance of the irregular fluctuations in the estimation of the variability is stressed by Landsberg (1958) and Conrad and Pollak (1950) in their examination of temperature as a climatological element.

The choice of the specific cities was dictated by two main reasons:

1. More than half the total population of Greece is concentrated in these cities, as well as large number of industries and craft enterprises. For this reason, the regions have the largest energy requirements. Investigating them and examining in detail the climatic statistics of sunshine duration or solar radiation will help to apply solar technology in any country that needs energy.

2. These three cities are situated along the 600-km long axis which runs from NNW to SSE, and the distances between them are approximately equal (see Fig. 1). The axis extends over the whole of Greece, since the country has a similar orientation.

Considering the Greek area, there is only one relevant work (Karapiperis, 1965) which refers to Athens and uses daily values for five consecutive years. In addition, there is a number of publications on sunshine duration and solar radiation, over a variety of areas and the whole country of Greece as well (Charantonis, 1985; Flocas, 1980; Flocas et al., 1988; Karapiperis et al., 1974; Livadas et al., 1977; Bloutsos and Pennas, 1986; Maheras and Tselepidaki, 1989; and Pennas, 1976). The number of publications and the different approaches to the subject are due to the very important role played be the effects of geography (latitude, relief, continentality) in each particular region of Greece.

2. Data and method

The data on sunshine duration were obtained from archives of the Department of Meteorological Station of Thessaloniki, for the station of Thessaloniki, from the archives of the National Observatory of Athens, for the station of Athens, and from the archives of the National Hellenic Meteorological Service, for the station of Iraklion. The first two stations are situated in the continental area of Greece, while the latter station is positioned on Crete, the largest island of the Aegean Sea.

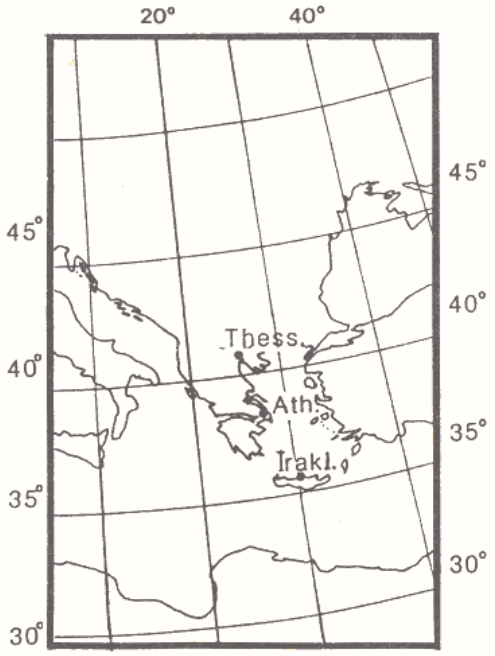

Figure 1. Map of the Mediterranean area indicating the location of the three meteorological stations examined.

Daily measurements of the sunshine duration are used, for the same decade (1971–1980) for all the stations. The sunshine duration was measured in the same manner at the three stations, by using the Cambell-Stokes recorders (W.M.O., 1971). It is known that they measure the sunshine duration with an error of ±5 min. Obstructions in the recording of the sunshine duration are considered to be negligible.

The variations from one day to the next, which are known as interdiurnal variability, were calculated by using the equation:

$$ID.V. = SD_{j+1} - SD_j \tag{1}$$

where SD_j is the sunshine duration on the j-th day. The 3533 interdiurnal values for each meteorological station were classified into steady conditions and changes. The criterion used for the steady condition is given by:

$$|ID.V.| \leq 1 \text{ hour of sunshine duration.} \tag{2}$$

The interdiurnal variabilities of sunshine duration are studied in two different ways: irrespective of sign and separately as rises and falls. The latter were gathered into three groups according to the number of hours per day as follows: 1.1–3.0, 3.1–5.0, and >5.0. Their distributions over the year were studied separately for each station.

3. Discussion and conclusions

Table 1 depicts the mean daily sunshine duration values recorded during the examined decade and the theoretical monthly amounts. Since the latitude differences among the three stations are very small (approximately 5°), the differences between the theoretical values are not significant. The yearly average values are: for Thessaloniki – 4456.2, for Athens – 4451.9 and for Iraklion – 4448.1 hours.

Table 2 shows that the highest values of the *ID.V.* are encountered at the northernmost station. This is obvious if one examines either the actual fluctuations irrespective of sign, or separately the rises and falls. It is evident that there is a pronounced negative tendency from the north to the south and from the cold to the warm period.

Since the physical obstructions are considered to be negligible, the encountered differences in the *ID.V.* of sunshine duration should be due to the weather systems which are responsible for different cloudiness over the three areas.

The months of the warm period, June, July, August and September, show the lowest values for the three stations. The aforementioned decreasing tendency from the north to the south becomes more pronounced during these months, resulting in *ID.V.* values at Iraklion about half of those encountered at Thessaloniki during the months of July and August.

Table 1. Geographical coordinates of the meteorological stations and mean daily sunshine duration (in hours) with the corresponding standard deviations for the period 1971—1980. The theoretical values are provided for each month (in hours).

	Thessaloniki $\varphi = 40°31'N$ $\lambda = 22°57'E$		Athens $\varphi = 37°58'N$ $\lambda = 23°58'E$		Iraklion $\varphi = 35°20'N$ $\lambda = 25°11'E$		Fraction of theoret. insolation			Theoretical monthly values		
	(in hours)									(in hours)		
	M	σ	M	σ	M	σ	Th.	At.	Ir.	Th.	At.	Ir.
J	3.55	3.52	4.13	3.27	3.68	2.94	0.37	0.42	0.36	299.0	305.9	312.4
F	4.46	3.80	4.79	3.40	4.17	3.32	0.42	0.44	0.38	298.5	302.1	305.6
M	5.15	3.90	6.15	3.57	6.02	3.46	0.43	0.52	0.50	370.5	371.0	371.3
A	7.19	4.14	7.60	3.92	7.47	3.90	0.54	0.58	0.57	398.9	395.7	352.6
M	8.87	3.89	9.82	3.39	9.81	3.13	0.61	0.69	0.70	447.7	441.2	435.0
J	10.33	3.21	11.61	2.24	11.86	1.97	0.69	0.79	0.82	451.1	442.9	435.1
J	11.09	2.61	11.96	1.73	12.10	1.15	0.75	0.82	0.85	457.3	449.9	442.8
A	10.27	2.73	11.44	1.62	11.14	1.28	0.75	0.84	0.83	426.3	421.8	417.3
S	8.35	3.09	9.06	2.14	9.37	2.22	0.67	0.73	0.76	374.2	373.0	332.0
O	5.83	3.74	6.84	3.29	6.22	3.40	0.52	0.61	0.55	344.8	347.4	350.0
N	4.66	3.55	5.83	3.15	5.10	2.88	0.47	0.57	0.49	298.3	304.1	309.7
D	4.14	3.42	4.57	3.21	3.79	2.96	0.44	0.48	0.39	289.6	296.9	304.3
										(4456.2)	(4451.9)	(4448.1)

Table 2. Interdiurnal variability of sunshine duration at Thessaloniki (TH), Athens (AT) and Iraklion (IR).

	Average change irrespective of sign (in hours)			Average rises (in hours)			Average falls (in hours)		
	TH.	AT.	IR.	TH.	AT.	IR.	TH.	AT.	IR.
J	4.6	4.4	3.7	4.8	4.2	4.0	4.5	4.3	3.6
F	4.6	3.8	3.8	4.6	3.7	4.0	4.7	3.9	3.8
M	4.6	4.1	4.1	4.3	4.1	4.3	5.0	4.2	4.0
A	5.0	4.3	4.6	4.7	4.5	4.7	5.2	4.3	4.5
M	4.9	4.5	4.0	4.8	4.6	4.1	4.9	4.4	3.9
J	3.9	3.2	3.0	3.8	3.4	3.2	4.2	2.9	2.9
J	3.5	2.7	2.0	3.5	2.5	2.1	3.4	2.9	2.0
A	4.0	3.1	2.4	4.0	3.3	2.2	4.0	3.2	2.7
S	3.5	3.0	3.2	3.9	3.3	3.1	3.5	2.8	3.4
O	4.6	3.9	3.9	4.7	4.4	4.0	4.4	3.8	3.9
N	4.2	3.8	3.2	4.0	3.8	3.2	4.4	3.9	3.3
D	4.4	4.3	3.8	4.4	4.1	3.8	4.6	4.5	3.7

During the warm period, a zonal circulation is prevailing, with winds blowing from the west to the east on the northern edge of the subtropical high, which affects the southern Europe and the Mediterranean region. In addition, small number of depressions, which move from the NW Europe towards the Balkan area and Black Sea or from the Scandinavian area towards the Black Sea, affect with their southern edges the northern area of Greece more than the southern parts (Maheras, 1989). As a consequence, there are light rains and thunderstorms,weather conditions which produce variability from one day to the next without lowering the values of sunshine duration (Balafoutis, 1987).

The differences in the cold period can be attributed to the prevailing submeridional atmospheric circulation over the central Europe and east Mediterranean, which results in small differences between the northern and southern Greek stations (Maheras and Kolyva-Mahera, 1990). Depressions of the Atlantic origin, which move over the western and central Europe, are preferably directed towards the Greek area (Maheras, 1988). This is due to the existence of the continental anticyclone, situated over the eastern Europe, and an increase of the baric gradient over the eastern Mediterranean area (Makrogiannis and Sahsamanoglou, 1990).

The months of April and May, which somehow fall between the cold and warm period, show much higher values for the three examined stations. The reason for this is an increased influence of migrating depressions during these months. Specifically, the Greek area is affected by depressions reaching the area either from the Atlantic through Gibraltar (Flocas, 1988) or from the north Africa (Prezerakos, 1985). This results in a »changeable« weather, with interchanges between the sunny and cloudy days, supporting the low percentage of steady conditions during these months (Fig. 2).

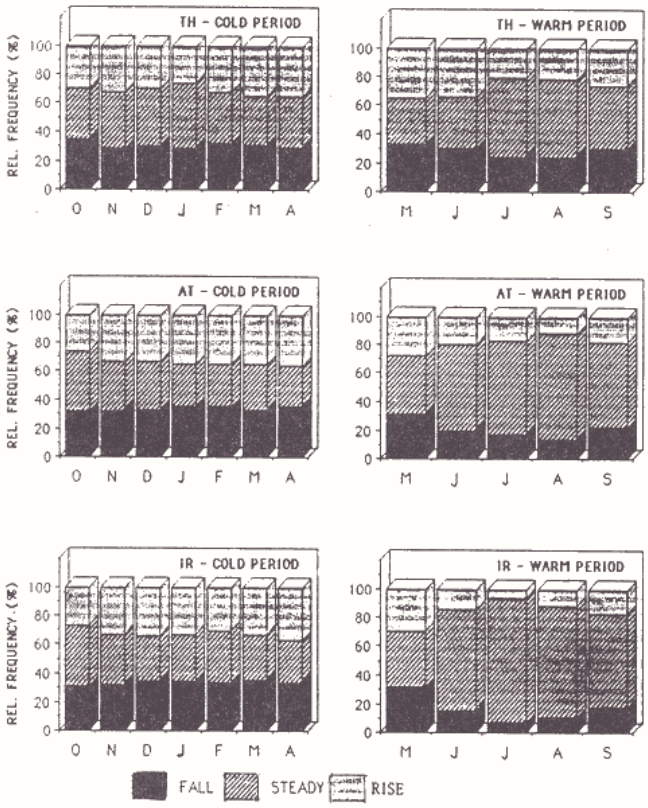

Figure 2. Interdiurnal variability of sunshine duration for the three meteorological stations, during the cold and warm period.

Table 2 shows that the lowest values of the *ID.V.* occur during the month of July, which seems to be consistent for the three stations. The station of Iraklion displays almost half of the value indicated at the Thessaloniki station, that is 2.0 and 3.5 hours, respectively.

It is noteworthy to mention a characteristic feature of the Iraklion station. Not a single day of the month of July for the years 1978 and 1980 did indicate *ID.V.*, which means that the differences of the sunshine duration from one day to the next were less or equal to 1 hour, according to the aforementioned limits. The reason is a steady airstream of northerly winds, the Etesians, which prevail over the Aegean Sea (Arseni et al., 1988). These winds, resulting from the combination of a high pressure system in the central Europe and a low pressure system in the eastern Mediterranean, produce many extremely sunny days and high percentages of steady conditions. The wind pattern, combined with the geographical position of the three meteorological stations, provides less effect on the northern than the southern stations.

Figure 2 depicts the three conditions, as they have been defined above, for the three stations and for the cold and warm period. Examination of the cold period reveals that the differences among the three conditions are small, while the main characteristic during the warm period is steady condition, which is the dominant one. These features are displayed more convincingly in Figure 3, where the average values for each period are used.

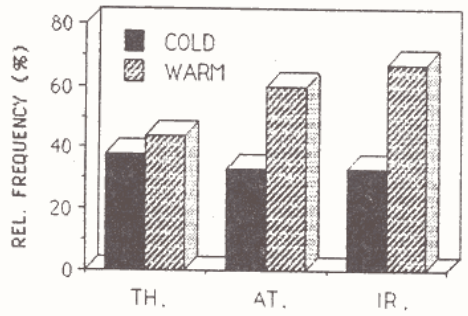

Figure 3. Steady conditions during the cold and warm period.

By examining the percent relative frequencies of rises and falls for the three classes of Figure 4, it is observed that during the warm period all the classes have the highest values at the northernmost station and the lowest in the southernmost one. This characteristic does not appear in the cold period. It is believed that it is due to the local northern descending wind called »Vardaris« at Thessaloniki. It blows at great speed and is dry (Arseni-Papadimitriou and Maheras, 1985; Maheras et al., 1982). Thus, it suppresses cloud formation and increases the otherwise low sunshine duration values during this period. The significant differences are observed in the first class: 1.1–3.0 *ID.V.* Thessaloniki has the smallest percentage in this class, and for this reason highest values are observed in Table 2.

The study of the 10-year data on *ID.V.* of sunshine duration at three stations may be summarized as follows:

(a) – A negative trend is observed from the north to the south and from the cold to the warm period.

(b) – The highest values are encountered in the months of April and May, while the lowest occur in July. The highest values are probably due to the trajectories of the weather systems, which affect the northeastern area of Mediterranean during the above mentioned months. The lowest values result from the combination of the high pressure systems of the central Europe and the low pressure system of the eastern Mediterranean. These formations influence heavily the climate of the Aegean Sea islands and also affect the weather of the eastern coast of the continental area of Greece, during the entire summer period.

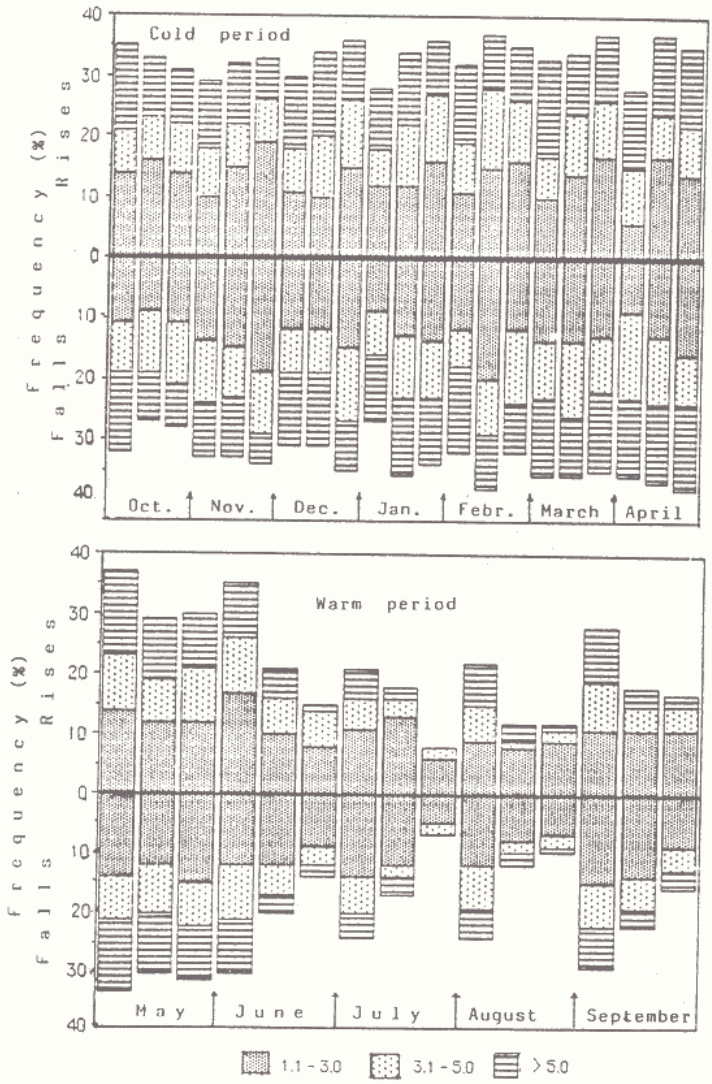

Figure 4. The three different classes of rises and falls, for the cold and warm periods during the years 1971–1980. For each month, the first column represents Thessaloniki, the second Athens and the third Iraklion.

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