WINTER AND SUMMER INDICES IN THESSALONIKI

by

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Abstract. *In this paper we define seasonal (winter and summer) indices for the city of Thessaloniki during the period 1931-1974.*

Through the combination of the two meteorological parameters of air temperature (T) and sunshine duration (S) with the number of days with snow (N_s) for winter and the amount of rainfall (R) for summer, the weather indices for winter (I_w) and summer (I_s) are expressed as follows:

$$I_w = 10T + \frac{S}{4.4} - 2.3N_s$$

$$I_s = 10T + \frac{S}{6.5} - \frac{R}{5.4}$$

The winters are classified in five categories, as severe, cold, normal, mild, very mild, and summers as well (very poor, poor, good, very good).

According to the above classification, during the period examined we had two cases of winters characterized as «severe», and thirteen winters characterized as «mild», while one summer only has been characterized as «very poor», and three as «very good».

Finally the incidence probability for the occurence of each class of winter and summer is also given.

INTRODUCTION

As we stated in a previous paper[6], the classification of winters (December-February) and summers (June-August) as to their degree of coldness and warmth, is of particular interest, because thermal anomalies occuring in an area, highly influence not only its national economy but also every activity human.

Classification of winters seems to have been untill now the main

point of interest of Greek scientists such as *Aeginitis*[1], *Livathinos*[16], *Kyriazopoulos*[10,11], *Karapiperis*[9], *Flocas*[5] and others. Most of these researchers have based their classification and their definition of the degree of coldness of winters on the element of air temperature alone.

During the last decade however, more scientists (*i. e. Poulter*[18], *Fergusson*[3], *Hughes*[8], *Rackliff*[20], *Flocas*[6] and others) have been engaged in studying seasonal weather indices. Most of these propose various empirical formulas for seasonal indices (winter or summer), combining the main three meteorological parameters of air temperature, bright sunshine and rain or snow.

We, in this paper, undertake the study of seasonal indices at the city of Thessaloniki, and the classification of each winter as to the degree of coldness and each summer as to the degree of warmth.

MATERIAL

The basic material for drawing up this work, was the time-series of monthly mean air temperature values at the city of Thessaloniki

TABLE I

SUMMER (June, July, August)			WINTER (December, January, February)	
Air Temperature				
	Year	C°	Year	C°
warmest	1946	27.27	1955	9.74
2nd warmest	1954	27.03	1951	9.59
coldest	1949	24.40	1954	3.89
2nd coldest	1969	24.43	1932	4.00
Total Bright sunshine				
sunniest	1946	1118.53 hours	1957	483.00 hours
2nd sunniest	1938	1107.20 »	1932	458.50 »
dullest	1973	895.40 »	1972	227.30 »
2nd dullest	1972	931.40 »	1947	238.99 »
Total Rainfall				
Driest summer	1954	11.40 mm		
2nd driest summer	1938	21.30 mm		
wettest summer	1970	153.40 mm		
2nd wettest summer	1957	153.20 mm		
			Snow	No of days
Least number of winter days			1931, 1951	0.0
2nd least number of winter days			1955, 1961	1.0
Highest number of winter days			1954	25.0
2nd highest number of winter days			1963	20.0

during the 1892-1973 period (*Flocas-Arseni*[7]), rainfall data, numbers of days with snow as well as additional data on air-temperature and sunshine duration values for the period 1931-1974 have been taken from the series «Observations Météorologiques de Thessaloniki» published by the Meteorological Institute of the University of Thessaloniki[12,15,17].

From these data have been calculated the seasonal (winter and summer) values of air temperature, and the total sunshine duration for the winter (December-February) and the summer (June-August) quarter, separately for each year.

Also the total number of days with snow for the three winter months (Dec., Jan., Febr.) and the amount of rainfall (in mm) for the three summer mouths (June, July, August), have been calculated.

Based on the above data we have drawn Table I. Winters are allocated to the year in which the months of Jenuary and February fell.

The period examined for the city of Thessaloniki begins from the winter of 1930-1931, since the series of monthly mean values of sunshine duration (missing for the 1940-1945 interval) exists from 1.6.1930.

WINTER AMD SUMMER INDICES

The method followed for the determination of seasonal weather indices for the city of Thessaloniki, is that of *Poulter*[18], *Rackliff*[19], and *Davis*[2], which has been already applied by the author for the city of Atbens[6].

During a winter season, the total number of days on which snow is recorded is more important for determining the degree of its severity than the amount of precipitation recorded during the three winter months. Because great rainfalls in winter may bring floods and disaster in tbeir wake, yet they are not considered quite as important as the results of the issolation of whole areas and the paralyzing of communications from heavy and prolonged snowfalls.

It is also well-known that bright sunshine is an element that arouses in a great extent every human activity; the psychological impact of bright sunshine in winter, is considerable and should not be understimated.

Moreover, the element of air temperature alone is not enough for the determination of the degree of coldness of a winter season in a certain area; since it is possible to have small temperatures in the area examined, resulting from anticyclonic systems prevailing in the greek area (*Livadas*[13,14]) and considerable increase of sunshine duration (*Flocas-Pennas*[4]).

That is why, for the determination of a winter index, we should have a combination of the three meteorological parameters: air temperature, sunshine duration, and days of snow falling in the city of Thessaloniki.

According to *Rackliff*[20] and the author as well[6], the winter index (I_w) is defined as

$$I_w = W_1 T + W_2 S - W_3 N_s$$

where: T = mean temperature ($^\circ$C) for December, January, February.
S = total bright sunshine (hours) for the three months.
N_s = total number of days of snow falling in the three above months.
W_1, W_2, W_3 = the weighting factors of the three elements, T, S, and N_s respectively.

The weighted value (W_3) of N_s is considered negative, since N_s is negatively correllated with T and S.

$$r_{TN_s} = -0.69 \qquad\qquad r_{SN_s} = -0.22$$

The range of extreme values for elements T, S, and N_s for the winter season, resultant from Table I, is 5.85, 225.70 and 25.00 respectively.

An arbitratry value of $W_1 = 10$, applied to the temperature range, gives a span of 58.5 units; then weights W_2 and W_3 would be:

$$W_2 = \frac{1}{4.4} \qquad \text{and} \quad W_3 = 2.3$$

Based on the values of the above three weights W_1, W_2, W_3, we have the following expression for the winter weather index:

$$I_w = 10T + \frac{S}{4.4} - 2.3 \, N_s$$

From this formula we have calculated the corresponding values of l_w separately for each year of the period examined, and then we constructed Table II.

The classification of summers and the determination of their degree as to warm or cool, dry or wet, sunny or dull, should be based on the combination of a number of meteorological parameters.

Recently such scientists as *Poulter*[18], *Rackliff*[19], *Hughes*[8], through a combination of the meteorological parameters of air temperature, bright sunshine, and rainfall or number of rain-days, have calculated the summer weather index (I_s) for various areas of Great Britain, while the author did the same for the city of Athens[6].

TABLE II

Winter weather index (Iw) in Thessaloniki, 1931-1974

I n d i v i d u a l   Y e a r

Decade Commencing	0	1	2	3	4	5	6	7	8	9	Decadal mean
1930		148	107	118	153	141	159	147	141	147	
1940	90	*	*	*	*	*	130	97	154	148	
1950	157	166	170	152	40	161	121	175	169	149	146
1960	157	183	129	66	134	133	167	149	134	123	138
1970	145	147	102	112	122						

* missing elements of sunshiue duration.

We give the following expression of I_s for the city of Thessaloniki, as we did for the city of Athens, by combining the above basic three meteorological parameters:

$$I_s = W'_1 \, T + W'_2 \, S - W'_3 \, R$$

where: T = mean temperature (°C) for June, July and August.
S = total bright sunshine (hours) for June, July and August
R = total rainfall (mm) for June, July and August.
W'_1, W'_2, W'_3 the weighting factors, so that T, S and R would be equally weighted.

In calculating the weights W'_1, W'_2, W'_3, *Poulter*[18] and *Rackliff*[19] have chosen their values so that the weighted range of each element should be nearly equal.

The method dor determination of W'_1, W'_2, W'_3 is the same one followed by the author[6] for the city of Athens, based on the relations found by *Davis*[2] $W'_1 \, \sigma_T = W'_2 \, \sigma_S = W'_3 \, \sigma_R$, between W'_1, W'_2, W'_3 and the values of standard deviation σ_T, σ_S, σ_R for T, S and R respectively.

The weighted value of R is negative, as R is negatively correlated with T and S.

At the city of Thessaloniki we have:

$$r_{TS} = 0.54, \qquad r_{TR} = -0.31, \qquad r_{SR} = -0.33$$

If we assume the weight W'_1 as arbitrary, and since the temperature T is expressed in degrees and their tenths, we have $W'_1 = 10$. From our calculations, we have found:

$$\sigma_T = 0.74, \qquad \sigma_S = 48.25 \qquad \sigma_R = 39.87$$

and since $W'_2 = \dfrac{10\sigma_T}{\sigma_S}$ and $W'_3 = \dfrac{10\sigma_T}{\sigma_R}$

we have $W'_2 = \dfrac{1}{6.5}$ and $W'_3 = \dfrac{1}{5.4}$

Consequently, the summer index (I_s) for the city of Thessaloniki is expressed as:

$$I_s = 10T + \frac{S}{6.5} - \frac{R}{5.4}$$

On the grounds of the above formula, we have calculated the I_s separately for each year of the period examined, and drawn Table III.

TABLE III

Summer weather index (Is) in Thessaloniki, 1931-1974

I n d i v i d u a l   Y e a r

Decade Commencing	0	1	2	3	4	5	6	7	8	9	Decade mean
1930		423	419	390	404	410	386	397	428	390	
1940	372	*	*	376	*	416	440	388	392	389	
1950	412	394	413	412	427	387	400	391	414	387	404
1960	404	398	395	398	377	394	383	378	391	385	390
1970	372	376	368	366	394						

* missing elements of sunshine duration

CLASSIFICATION OF WINTERS AND SUMMERS

Karapiperis[9] and the *author*[6] have effected a classification of winters in the Greek area, based mostly on data of air temperature.

For the classification of winters and summers at the city of Thessaloniki, using values of l_w and I_s, we follow at present the same process as for the city of Athens *(Flocas[6])*.

On the basis of data contained in Table II and III we have calculated the mean values of I_w and I_s, and their standard deviations σ_w and σ_s and we obtained:

$$\overline{I_w} = 137 \qquad \sigma_w = 29.01$$

$$\overline{I_s} = 396 \qquad \sigma_s = 17.21$$

TABLE IV

Classification of winters in Thessaloniki, 1931-1974.

Cold and Severe winters				Mild and very Mild winters			
Winters	I_w	Order	Ccassif.	winters	I_w	Order	classif.
1932	107	6th	cold	1934	153	11th	mild
1933	118	7th	»	1936	159	8th	»
1940	90	3rd	»	1948	154	10th	»
1947	97	4th	»	1950	157	9th	»
1954	40	1st	severe	1951	166	6th	»
1956	121	9th	cold	1952	170	3rd	»
1963	66	2rd	severe	1953	152	12th	»
1972	102	5th	cold	1955	161	7th	»
1973	119	8th	»	1957	175	2nd	»
				1958	169	4th	»
				1960	157	9th	»
				1961	183	1st	»
				1966	167	5th	»

According to the values of l_w and I_s, and following our previous classification[6] we distinguish winters in five categories (severe, cold, normal, mild, very mild) and summers in another five categories (very poor, poor, normal, good, and very good).

Based on the above classification we have drawn Tables IV and V, and Graph I, illustrating the variation of l_w and I_s from year to year, during the period examined.
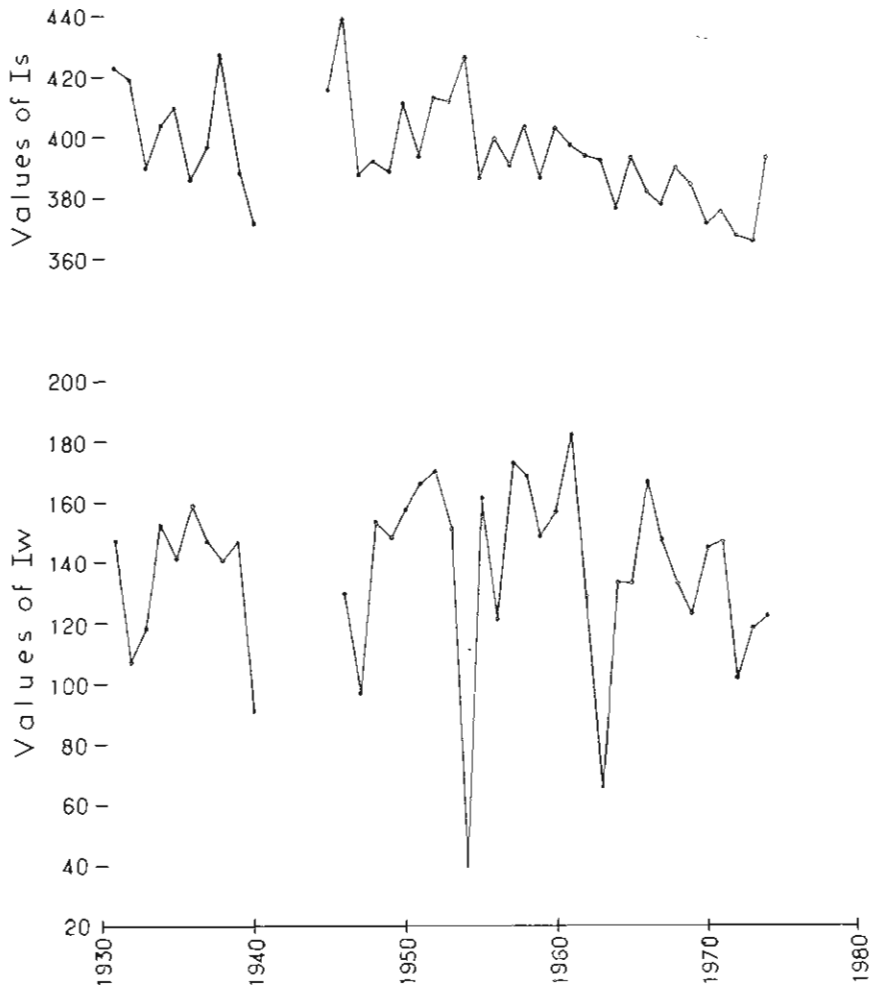
GRAPH I

Year by year variation of Winter and Summer Indices in Thessaloniki, 1931-1974.

TABLE V

Classification of summers in Thessaloniki, 1931-1974

Poor and very poor summers				good and very good summers			
Summers	I_s	Order	classif.	summers	I_s	Order	classif.
1936	386	9th	poor	1931	423	4th	good
1940	372	3rd	poor	1932	419	5th	»
1943	376	4th	»	1935	410	10th	»
1964	377	5th	»	1938	428	2nd	very good
1966	383	7th	»	1945	416	6th	good
1967	378	6th	»	1946	440	1st	very good
1969	385	8th	»	1950	412	9th	good
1970	372	3rd	»	1952	413	8th	»
1971	376	4th	»	1953	412	9th	»
1972	368	2nd	»	1954	427	3rd	very good /
1973	366	1st	very poor	1958	414	7th	good

CONCLUSIONS

1. During the 1931-1974 period examined herein, we observe two cases of severe winters in Thessaloniki; namely those of 1953-54 and 1962-63. The winter of 1953-54 was characterized as «severe» in the cities of Thessaloniki and Larissa in a previous paper of ours[6], while that of 1962-63 was characterized as «cold» in that same paper; the same winter was characterized as extremely severe in Manchester (*Raybould*[20]) and Armagh (*Rackliff*[19]).

For the 1941 - 42 winter, holding first place among severe winters in Thessaloniki (*Flocas*[5]) we have no data of sunshine duration available, for the calculation of I_w.

We also distinguish five cases of cold winters (Table IV); of these, that of 1931-32 has been characterized as severe at Athens[6] and Larissa and Thessaloniki as well (*Flocas*[5]) while those of 1932-33 and 1939-40 are also mentioned as cold in Larissa and Thessaloniki[5].

It should also be noted that the winter of 1953 - 54 started early and was prolongated till April[5], while that of 1931 - 32 was prolongated till the month of March and that of 1939 - 40 till the month of April[5].

We distinguish also 12 cases of mild winters during the period examined, with that of 1960 - 61 coming first; as a matter of fact this winter slightly differs from a very mild one.

Mild or very Mild winters in the above period are characterized those of 1935 - 36, 1950 - 51, 1954 - 55, and 1959 - 60 for the three cities of Athens, Larissa, and Thessaloniki, those of 1947 - 48 for Athens and Larissa (*Flocas*[5,6]) and those of 1951 - 52, 1956 - 57, and 1960 - 61 for Athens only[6].

Almost 77% of the winters characterized as mild for the city of Thessaloniki, were characterized as such for the city of Athens as well.

2. During the whole period examined, only one summer, that of 1973, has been characterized as very poor (very cool, wet, dull). We should also mention the poor summer of 1972, that slightly differs from a very poor one. The sunshine duration recorded in that summer (from June to August) is by 73.3 hours shorter than normal (1014.7 hours) while the amount of rainfall is by 61.8 mm higher than normal (79.9 mm).

On the other hand the summers of 1938, 1946 and 1954 are characterized as very good (very warm, dry, sunny); that of 1946 being the sunniest, warm and dry and the one of 1954 warm, sunny, and the driest of all.

It is also worth mentioning that the summers of 1931 and 1932, characterized as «good» (warm, dry, and sunny) are very near to the characterization of «very good», having total sunshine duration >1080.0 hours and rainfall amounting to<45.0 mm.

Almost 82% of the summers characterized as «good» or «very good» for the city of Thessaloniki, are also characterized as such for the city of Athens as well[6].

3. In all the 1931 - 1974 period examined (leaving out the 1941 - 45 interval), the most «severe» winter is that of 1953 - 54 ($I_w = 40$) and the most «mild» that of 1960 - 61 ($I_w = 183$).

According to the new classification process[6] for winters, a winter is characterized as «severe» when $I_w \leqslant 88$, «cold» whem $I_w \leqslant 122$, «very mild» when $I_w \geqslant 186$, and «mild» when $I_w \geqslant 152$.

This new classification process fully agrees with that previously followed by the author for the city of Thessaloniki[6]. As a matter of fact every winter of the 1931 - 74 period, previously characterized as «severe» or «cold», receives the same characterization again, except for the two winter seasons of 1933 - 34 and 1948 - 49, having sunshine duration longer than normal by almost 89.6 hours, their number of days with snow being≤3.0, while the mean air temperature has been below normal. This fact should be attributed to anticyclonic systems prevailing in the area of Greece, and producing a sensible increase

of sunshine duration (*Flocas*[4]) and a fall of air temperature (*Livadas*[13,14]) in the above area. The first of the above two wiuters is now characterized as mild, and the second as normal.

Moreover, by the new classification process we find that winters of 1932-33, 1946-47, 1955-56, 1971-72, and 1972-73 are characterized as cold. The same applies for all winters characterized as mild, except for those of 1930-31, 1938-39, and 1969-70 which have been characterized as «normal» but slightly differ from being «mild». Also «mild» are characterized the winters of 1933-34, 1949-50, 1951-52, 1956-57, 1957-58 and 1960-61; the winters of 1951-52, 1956-57 and 1960-61 have been characterized as mild in Athens too[6].

4. A «very good» summer, during the period examined, has been that of 1946 ($I_s = 440$); and a «very poor» one, that of 1973 ($I_s = 366$).

A summer is classified as «very good» when $I_s \geqslant 426$, as «good» when $I_s \geqslant 406$ «very poor» when $I_s \leqslant 366$ and «poor» when $I_s \leqslant 386$.

Summers characterized as «good» or «very good» in Thessaloniki are found to be so in Athens too, except for those of 1931 and 1932 which have been characterized as «normal» for Athens.

It should be mentioned that a number of summers classified as «poor» or «very poor» have been observed in the area examined during the last decade. Out of 11 such summers, 8 (73%) have occured between 1964-1974 (Graph I, Table V).

5. The incidence probability for a «severe» or «cold» winter at Thessaloniki is 23.1%, for a «mild» or «very mild» 33.3%, and that for a «normal» one is 43.6%.

To the same, the incidence probabilities have as follows: «poor» or «very poor» 26.8%; «good» or «very good» 26.8%, and for «normal» 46.4%.

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ΠΕΡΙΛΗΨΙΣ

ΚΑΙΡΙΚΟΙ ΔΕΙΚΤΑΙ ΧΕΙΜΩΝΟΣ ΚΑΙ ΘΕΡΟΥΣ ΕΙΣ ΘΕΣΣΑΛΟΝΙΚΗΝ

Ὑπὸ

ΑΠΟΣΤΟΛΟΥ Α. ΦΛΟΚΑ

Εἰς τὴν παροῦσαν ἐργασίαν προσδιορίζονται ἐποχικοὶ καιρικοὶ δεῖκται (χειμῶνος, θέρους) διὰ τὴν πόλιν τῆς Θεσσαλονίκης κατὰ τὴν χρονικὴν περίοδον 1931-1974.

Διὰ συνδυασμοῦ τῶν δύο μετεωρολογικῶν παραμέτρων θερμοκρασίας ἀέρος (T) καὶ τῆς διαρκείας ἡλιοφανείας (S) μετὰ τοῦ ἀριθμοῦ (N_s) ἡμερῶν πτώσεως χιόνος διὰ τὸν χειμῶνα καὶ τοῦ ὕψους βροχῆς (R) διὰ τὸ θέρος, προσδιορίζονται οἱ καιρικοὶ δεῖκται χειμῶνος (I_w) καὶ θέρους (I_s) ἐκφραζόμενοι ἀντιστοίχως ὑπὸ τῶν τύπων:

$$I_w = 10T + \frac{S}{4.4} - 2.3 \ N_s$$

$$I_s = 10T + \frac{S}{6.5} - \frac{R}{5.4}$$

Περαιτέρω οἱ χειμῶνες ταξινομοῦνται εἰς πέντε κατηγορίας (severe-δριμύς, cold-ψυχρός, normal-κανονικός, mild-ἤπιος, very mild-γλυκὺς) καὶ τὰ θέρη ἐπίσης εἰς πέντε κατηγορίας (very poor-πολὺ ψυχρό, ὑγρὸ καὶ ἀνήλιο, poor-ψυχρό, ὑγρὸ καὶ ἀνήλιο, normal-κανονικό, good-θερμό, ξηρὸ καὶ ἡλιοφεγγές, very good-πολὺ θερμό, ξηρὸ καὶ ἡλιοφεγγές).

Σύμφωνα μὲ τὴν ταξινόμησιν αὐτήν, εἰς Θεσσαλονίκην κατὰ τὴν μελετωμένην περίοδον διεκρίναμεν ἐπικράτησιν ἀφ' ἑνὸς μὲν δύο περιπτώσεων χειμώνων ὡς severe καὶ 13 ὡς mild, ἀφ' ἑτέρου δὲ μιᾶς περιπτώσεως θέρους ὡς very poor καὶ τριῶν ὡς very good.

Τέλος, δίδεται ἡ πιθανότης διὰ τὴν ἐπικράτησιν μιᾶς ἑκάστης κατηγορίας χειμῶνος καὶ θέρους.