Mediterranean Climatic Character in the Annual March of Precipitation

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The aim of the investigation is on the basis of the annual distribution of precipitation, and by suitable quantitative characteristics, distinguishing between the continental climatic type, characterizable by the summer maximum, and the Mediterranean one, characterizable by the winter maximum, in Hungary, Europe and the Mediterranean countries, respectively.

By the introduction of a suitable Mediterranean index (*MI*), as it is called, and by the calculation of this for several stations, we can obtain a survey of the regional distribution of the two kinds of climatic types.

Further on, we surveyed the *120*-year (*1870—1989*) precipitation series of Budapest and Szeged, and, according to the individual years, investigated the character of the *MI*. For the sake of exploring the possible periodic repetition, the Fourier analysis of the *120*-year *MI* series has been carried out.

Finally, we looked for a connection between the *MIs* of the two stations and the sea-level pressure anomalies of *17* European and Mediterranean stations. As a result we got that in Hungary, in case of an early summer well developed subtropical anticyclone, an autumn precipitation maximum is to be expected; while in case of a weak anticyclone, an early summer precipitation maximum.

Mediterrán klímajelleg a csapadék évi menetében. A vizsgálat célja az, hogy a csapadék évi eloszlása alapján megfelelő mennyiségi jellemzőkkel megkülönböztessük a nyári maximummal jellemezhető kontinentális és a téli maximummal jellemezhető mediterrán klímatípust Magyarországon, Európában, illetőleg a mediterrán országokban.

Egy megfelelő, úgynevezett Mediterrán index (*MI*) bevezetésével és ennek több állomásra való kiszámításával áttekintést nyerhetünk a kétféle klímatípus területi eloszlásáról.

A továbbiakban áttekintettük Budapest és Szeged *120* éves (*1870—1989*) csapadéksorát, és az egyes évek szerint megvizsgáltuk az *MI* jellegét. Az esetleges periodikus ismétlődés felderítése érdekében elvégeztük a 120 éves *MI*-sorok Fourier-analízisét.

Végül kapcsolatot kerestünk az állomások *MI*-ei és *17* európai illetve mediterrán állomás tengerszinti légnyomási anomáliái között. Eredményként azt kaptuk, hogy Magyarországon kora nyári erős szubtrópusi anticiklon esetén őszi csapadékmaximum, míg gyenge anticiklon esetén kora nyári csapadékmaximum várható.

On the basis of the annual march of precipitation, Europe is divisible into three climatic regions:

1. *Region of atlantic character*: with comparatively small annual fluctuation of precipitation, the wettest month mostly (in about *72%* of the stations) in the colder half-year (in the months October—March).

2. *Region of continental character*: with moderate annual fluctuation of precipitation, the rainiest month almost exclusively (in about *97%* of the stations) in the warmer half-year (in the months April—September).

3. *Region of mediterranean character*: with comparatively great annual fluctuation of precipitation, the rainiest month in the over-whelming majority of cases in the winter half-year.

In the course of the attempt made at parting these three climatic characters, we have used the means of many years of *123* European and, in part, Turkish climatological stations (**Koppány, 1989**). Considering the wettest month of the year, the continental and Mediterranean characters are well separable from each other; in the former, the maximum precipitation occurs in the summer half-year, in the latter, in the winter one.

The aim of the present investigation is that, on the basis of a suitable quantitative character number, we should distinguish the continental and Mediterranean climatic characters in Europe; furthermore, we should investigate how the two climatic effects vary in the precipitation series longer than 100 years of two climatological stations of Hungary. For it is obvious that in a transitional zone, such as Hungary, the two kinds of climatic characters alternate, depending on the fluctuation of circulation.

Method and Objective

In the course of the previous investigation mentioned, we found that in the majority of the climatological stations of Mediterranean character, the wettest month of the year is October or November; while in the part of the climatological stations of continental character which lie near the Mediterranean region, the rainiest month is May or June (**Koppány, 1989**). The precipitation march characteristic of the Mediterranean, as well as the transitional continental-Mediterranean climate are shown, respecting 6 climatological stations, by *Fig. 1*. The Mediterranean character presenting itself in the annual march of precipitation is distinctly visible at the stations Palma de Mallorca (Balearic Isles) and Milan, while the double maximum (May—June and October—November), at the transitional stations: Skopje, Pécs, Balatonfüred and Lillafüred. Further 6 climatological stations serve as models for the illustration of the Atlantic and continental characters, as well as of the continental-Mediterranean mixed character (*Fig. 2*). Whereas Brussels, Le Havre and London show an Atlantic-type precipitation march, Prague shows a typically continental-type one, Budapest and Szeged show a mixed-type one.

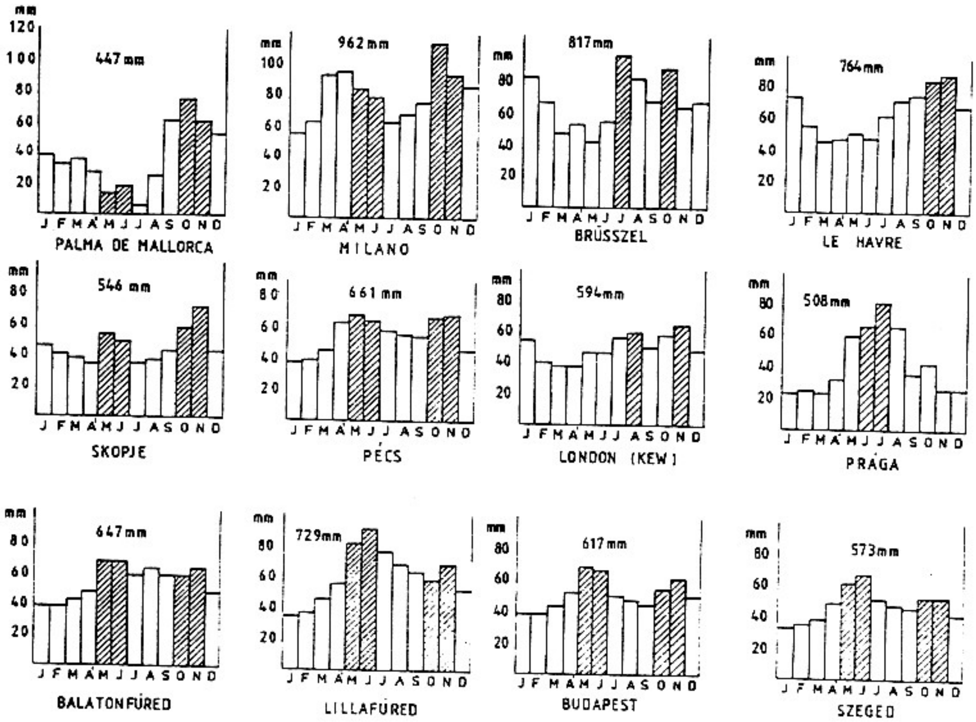

Fig. 1. Precipitation diagrams of the stations with mediterranean and transitional continental—mediterranean precipitation character

Fig. 2. Annual precipitation diagrams of the stations with atlantic, continental and continental—mediterranean precipitation character

For the quantitative characterizing of the Mediterranean character of precipitation we have brought in the following index:

$$MI = (P_{X\text{-}XI} - P_{V\text{-}VI})\cdot 100/P_{year}.$$

Here, MI is the Mediterranean precipitation index, $P_{X\text{-}XI}$ is the amount of precipitation of the months October + November in mm, $P_{V\text{-}VI}$ is the amount of precipitation of the months May + June in mm, P_{year} is the annual amount of precipitation in mm.

By calculating the MI for several climatological stations we obtain a survey of the regional distribution of the Mediterranean and continental climatic characters. The greater positive number we get in a given place for MI, the stronger there the Mediterranean character is, and vice versa: the greater negative value the MI has in some place, the stronger there the continental character of precipitation is. If somewhere the *MI* gives a value about zero, then there the Mediterranean and the continental effect are almost equal. Starting from this, we have determined the regional distribution of the *MI* for the part of Europe lying south of 50°N, as well as for Hungary.

As in certain parts of Hungary, the *MI* shows a slight continental character, we supposed that, regarding a long series of the years, the continental and Mediterranean effects present themselves alternately. Therefore we have investigated the precipitation series of two climatological stations which are in possession of at least *120* years' pluviometry, namely the data series of Budapest and Szeged between *1870* and *1989*. Questions laying claim to interest: 1. With what kind of relative frequency does the Mediterranean character occur over the years? 2. Is there a periodic repetition in the occurrence of the Mediterranean character? 3. Is there any connection between the *MI* and the anomalies of sea-level pressure?

Results

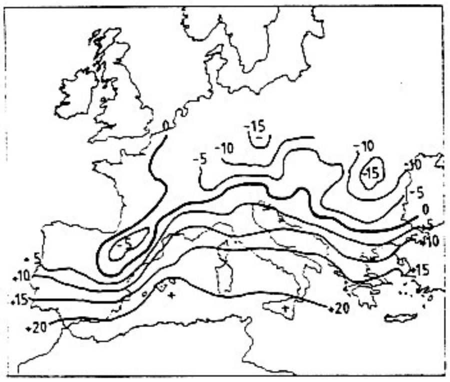

Fig. 3. Areal distribution of the Mediterranean index in Europe (1901—50)

The regional distribution of the Mediterranean index for the part of Europe south of 50°N has been determined by means of *49* (*+3*) stations (*Table I and II*), and is demonstrated in *Fig. 3*. It is visible from the figure that the line of zero value separating the areas of continental and Mediterranean character runs through the middle of the Balkan Peninsula, the south of Hungary, the Alps and the south of France as far as Spain, from where it turns with a sharp bend to the north. From this time onwards, however, it can no longer be considered as the dividing line mentioned, for in these Western European areas, the Atlantic climatic character holds true already.

Table I

The Mediterranean indices and the mean yearly amount of the precipitation of the stations of the network in Europe and about Europe (1901-50)

		MI	precip.			MI	precip.
1.	Porto	+2.17	1150	26.	Naples	+17.10	895
2.	Lisboa	+13.42	708	27.	Cagliari	+15.45	453
3.	Sevilla	+15.92	559	28.	Zürich	-7.66	1136
4.	Madrid	+6.65	436	29.	Genf	-0.12	852
5.	Zaragoza	-6.78	339	30.	Brussel	+6.97	817
6.	Barcelona	10.37	598	31.	London	+4.88	594
7.	Palma de M.	+22.60	447	32.	Prague	-15.74	508
8.	Valladolid	+1.66	362	33.	Salzburg	-11.10	1278
9.	La Coruna	+11.85	962	34.	Ljubjana	+4.14	1618
10.	Gibraltar	+21.60	815	35.	Zagreb	-0.46	864
11.	Marseilles	+13.74	546	36.	Belgrade	-7.88	701
12.	Ajaccio	+16.70	672	37.	Split	+8.33	816
13.	Bordeaux	+5.88	900	38.	Dubrovnik	+10.85	1272
14.	Toulouse	-6.07	659	39.	Skopje	+5.13	546
15.	Lyon	+0.37	813	40.	Sarajevo	+1.35	889
16.	Paris	-0.50	585	41.	Tirana	+12.44	1289
17.	Le Havre	+10.08	764	42.	Cluj	-16.64	613
18.	Brest	+1.60	1126	43.	Iasi	-11.40	518
19.	Tours	+1.74	689	44.	Bucharest	-10.23	440
20.	Nantes	+7.16	782	45.	Varna	-1.61	498
21.	Dijon	-1.22	739	46.	Sofia	-9.69	640
22.	Rome	+15.10	881	47.	Thessaloniki	+8.46	449
23.	Palermo	+22.02	772	48.	Athens	+16.95	405
24.	Milano	+4.57	962	49.	Istanbul	+13.80	679
25.	Florence	+8.30	795				

Table II

The Mediterranean indices and the mean yearly amount of the precipitation of the stations of the network in Hungary (1901-50)

		MI	precip.			MI	precip.
1.	Abádszalók	-4.18	502	19.	Pécs (Airfield)	+0.28	701
2.	Aggtelek	-7.22	622	20.	Szeged	-4.36	573
3.	Bácsalmás	-3.45	609	21.	Szentgotthárd	-5.87	817
4.	Baja	-2.84	599	22.	Szombathely	-3.28	700
5.	Balatonfüred	-2.47	647	23.	Villány	-1.15	697
6.	Békéscsaba	-5.15	563	24.	Zalaegerszeg	-4.16	745
7.	Cegléd	-4.04	545	25.	Lillafüred	-6.17	729
8.	Budapest	-3.40	617	26.	Győr	-3.14	541
9.	Debrecen	-4.27	585	27.	Komárom	-4.92	549
10.	Drávafok	-0.28	699	28.	Mosonmagyaróvár	-3.70	594
11.	Kaposvár	-3.28	715	29.	Kecskemét	-2.51	517
12.	Kőszeg	-5.52	779	30.	Pápa	-3.43	641
13.	Mohács	-1.44	624	31.	Sopron	-5.23	688
14.	Nagykanizsa	-2.32	777	32.	Székesfehérvár	-3.81	577
15.	Pécs (University)	+0.30	661	33.	Szolnok	-4.00	524
16.	Pécs (Mecsekalja)	+0.15	650	34.	Romhány	-2.20	585
17.	Misinatető	-0.14	723	35.	Kiskunfélegyháza	-2.46	540
18.	Pécs (T.T.College)	+0.29	683	36.	Orosháza	-4.31	533

South and north of the dividing line, the absolute value of the *MI* rapidly increases. In the southern, Mediterranean areas, a zonality parallel with the latitudes beautifully takes shape, with maximum *MI* values above *+20*. (Sicily, southern Spain.) In the northern, continental parts, the zonality is not so much definite, it is especially the Carpathian Basin that causes a big break in the run of the isobars. In the European parts investigated, the greatest negative *MI* values, those below *-15*, are found in Transylvania and Bohemia, two basin-type regions.

A more precise distribution of the *MI* in the territory of Hungary has been designed in *Fig. 4* by means of *36* stations (*Table II*). It can be seen that a (Mediterranean) area of a faintly positive value can only be disclosed in the surroundings of Pécs, while the rest of the country, without a more definite zonality, can be characterized by various, not very great negative values. (Continentality.) The regions with the largest negative *MI* values, those below *-5*, are found in the north-eastern, western and south-eastern parts of the country.

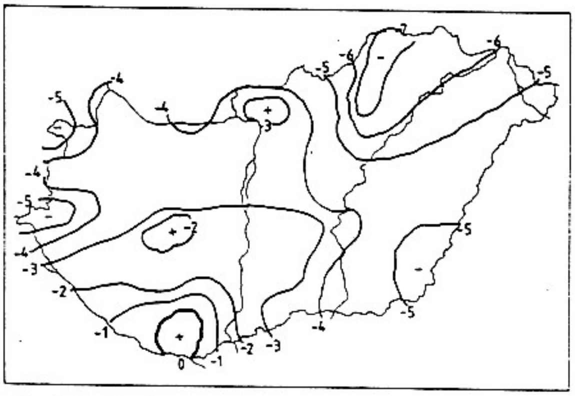

Fig. 4. Areal distribution of the Mediterranean index in Hungary (1901—50)

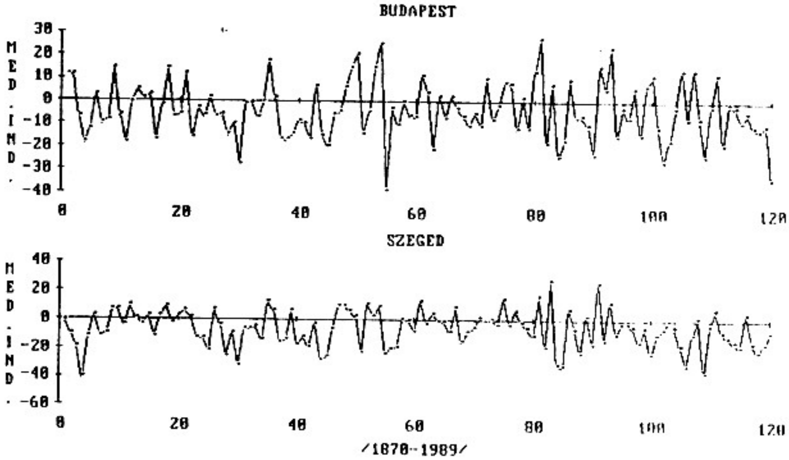

Fig. 5. March of the Mediterranean index in Szeged and Budapest (1870—1989)

Further, we surveyed the *120*-year (*1870-1989*) precipitation series of Budapest and Szeged. We counted up the values *MI* station by station and year by year so as to investigate the alternations of the Mediterranean and the continental effect. The way of walking of the *MI* is demonstrated on a chart in *Fig. 5*. It is visible that the fluctuation according to years is very great in both directions.

We have determined the proportions of the years with positive or negative indexes broken down according to *10* years, as well as in the relation of the whole *120*-year series (*Table III*). It is visible that with both stations the years with positive values occur in their entirety approx by a ratio of *1/3*; while with the *10*-year phases, the variety is great. (From *10%* to *60%*.) We also looked at how many times in the cases of the two stations indexes with identical signs occur in the same years. On the whole, approx in *1/6* of the cases the values are positive simultaneously; while in more than half of them they are negative simultaneously; that is in precisely *71·7%* of the cases the *MI* has identical signs.

Table III

The numbers and the proportions of the years with positive and negative Mediterranean indices in every 10 years and between 1870 and 1989 in Szeged and Budapest

	Szeged		Budapest		Sz—Bp	Sz—Bp
	+	-	+	-	++	--
1870—79	3	7	4	6	2	5
80—89	6	4	4	6	3	3
90—99	3	7	2	8	1	6
1900—09	3	7	2	8	2	7
10—19	4	6	4	6	3	5
20—29	4	6	2	8	2	6
30—39	3	7	4	6	1	4
40—49	4	6	5	5	1	3
50—59	4	6	3	7	3	6
60—69	2	8	5	5	2	5
70—79	1	9	2	8	—	7
80—89	2	8	1	9	1	8
Sum total	39	81	40	80	21	65
%	(32·5)	(67·5)	(33·3)	(66·7)	(17·5)	(54·2)

For further investigation of the closeness of the connection between the characters of the precipitation marches of the two stations, we calculated the correlation coefficient of the MI values. The coefficient happened to be $r = 0{\cdot}5808$, which even on a *1%* significance level relates to a very close connection with an identical sign (the critical value, in case of *120* pairs of value, is $p^{1\%} = 0{\cdot}23$). Thus, in the *120*-year precipitation series of the two stations, the years having either a Mediterranean or a continental character, as well as the order of magnitude of the indexes of these alternate in a rather identical manner.

With a view to the exploration of the possible periodic recurrence, we investigated the *120*-year *MI* series with the method of the Fourier analysis.

Having sorted the time series according to the presumed periods of T = *2—61* years, we detected the constants of the equations

$$y = A \sin(2/\pi x/T + U).$$

(A = amplitude, T = length of period, x = time in years, U = phase angle.) The amplitudes resulting have been expressed in the ratio of the expectancy $E = \sigma(\pi/n)^{1/2}$. (σ = standard deviation of the data, n = number of the members of data).

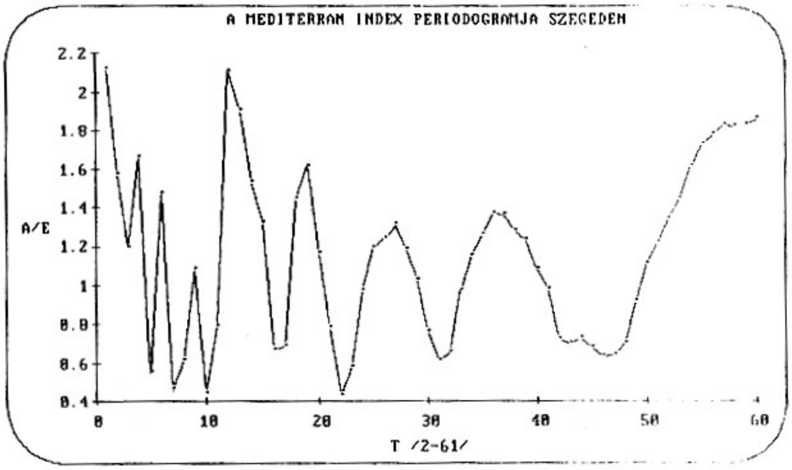

Fig. 6. Periodogram of the Mediterranean index in Szeged (1870—1989)

The values *A/E* resulting are demonstrated on a chart called a periodogram. In *Figs. 6 and 7* we can read the lengths of periods belonging to the exceptionally great amplitudes (values *A/E*) . In case of a *5%* significance level, the critical value equals 2, that is the period belonging to an *A/E* value greater than this can be accepted as real. The values *A/E* around 2 having been selected:
In the case of Szeged,

the *2-year (A/E = 2·19),*
13-year (A/E = 2·11),
and *14-year (A/E = 1·90)* periods,

in the case of Budapest,

the *8-year (A/E = 1·82),*
and *15-year (A/E = 2·14)* periods look real.

Further on, we looked for a connection between the anomalies of the Mediterranean index and those of sea-level pressure. We considered the pressure series of *17* European and Mediterranean-region stations in the relation of the years between *1951* and *1980*, broken down from month to month. The difference between the amount of the October and November anomalies (with signs) and the amount of the May and June anomalies was calculated for every single year in mbs,

$$LA = \Delta p(X+XI) - \Delta p(V+VI).$$

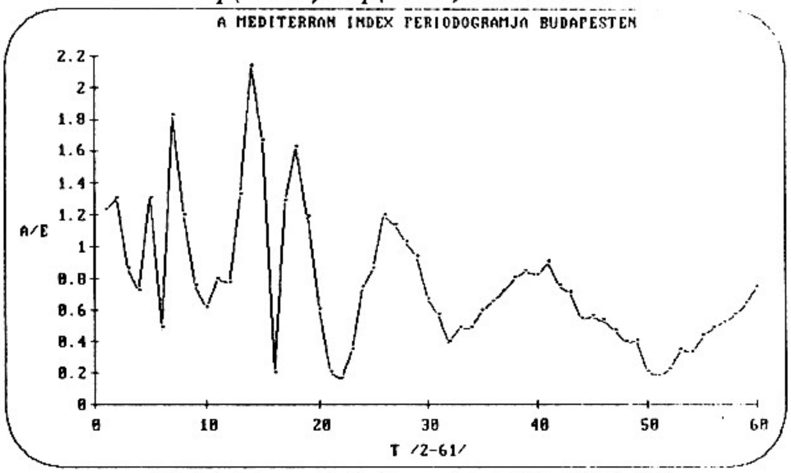

Fig. 7. Periodogram of the Mediterranean index in Budapest (1870—1989)

The *MI* series of Budapest for the corresponding years is given already.

According to our supposition, to the positive values *MI* (the precipitation maxima of October and November) there belong negative values *LA*, that is in May—June the high-pressure subtropical anticyclone draws more northward than on the average; with that also the northern boundary of the drier region, and vice versa.

By the help of the correlation coefficient, we looked at which regions are those to which there belong *LA* values between which and the Budapest *MI* values a contrary march is positively demonstrable. In case of *30* pairs of data, the *5*, *1*, as well as *0·1%* significance levels are

$$p_{30}^{5\%} = 0{\cdot}3494,\ p_{30}^{1\%} = 0{\cdot}4487, \text{ and } p_{30}^{0,1\%} = \cdot 0{\cdot}5541.$$

The correlation coefficients resulting are illustrated in *Fig. 8* on a chart; the negative values amounting to an at least *5%* level, framed. As was to be expected, the marches of the *MI* and *LA* opposite in meaning compared with one another are mainly characteristic of stations of the Mediterranean region.

Having performed the calculation corresponding to the preceding one besides Budapest for Szeged as well, we get a similar result. The correlation coefficients calculated are to be found in *Table IV*.

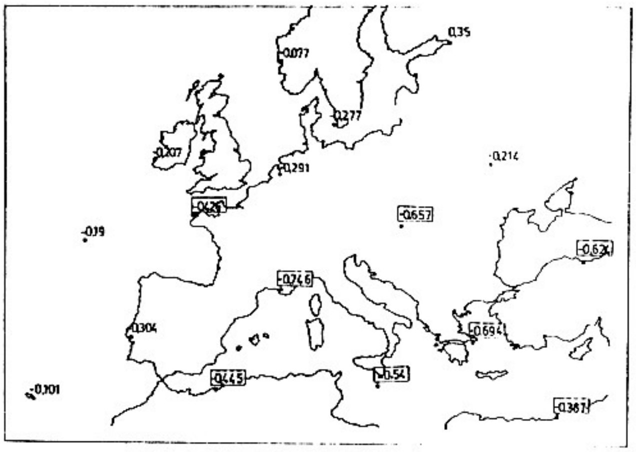

Fig. 8. Areal distribution of the correlation values between the mediterranean index in Szeged and the anomalies of air pressure in case of some station

Table IV

Correlation values between the mediterranean indices
and the air pressure anomalies of the listed stations (1951—80)

	Budapest	Szeged
Bergen	-0·077	0·054
Valentia	-0·207	-0·197
De Bilt	-0·291	0·017
Copenhagen	-0·277	-0·290
St. Petersburg	0·350	0·051
Kiev	-0·214	-0·560
Ship K	-0·190	-0·115
Brest	-0·426	-0·300
Marseille	-0·746	-0·550
Budapest	-0·657	-0·766
Samsun	-0·624	-0·618
Funchall	-0·101	-0·280
Lisboa	-0·304	-0·343
Oran	-0·445	-0·402
Malta	-0·540	-0·430
Athens	-0·694	-0·588
Alexandria	-0·387	-0·215

Consequently, in the years in which the subtropical anticyclone is well developed in early summer (a negative *LA*), in the precipitation march of Hungary, the Mediterranean character prevails, (an autumnal precipitation maximum — a positive *MI*), while in case of a weak anticyclone in early summer (a positive *LA*), it is the continental character which comes to the fore. (An early summer precipitation maximum — a negative *MI*.)

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